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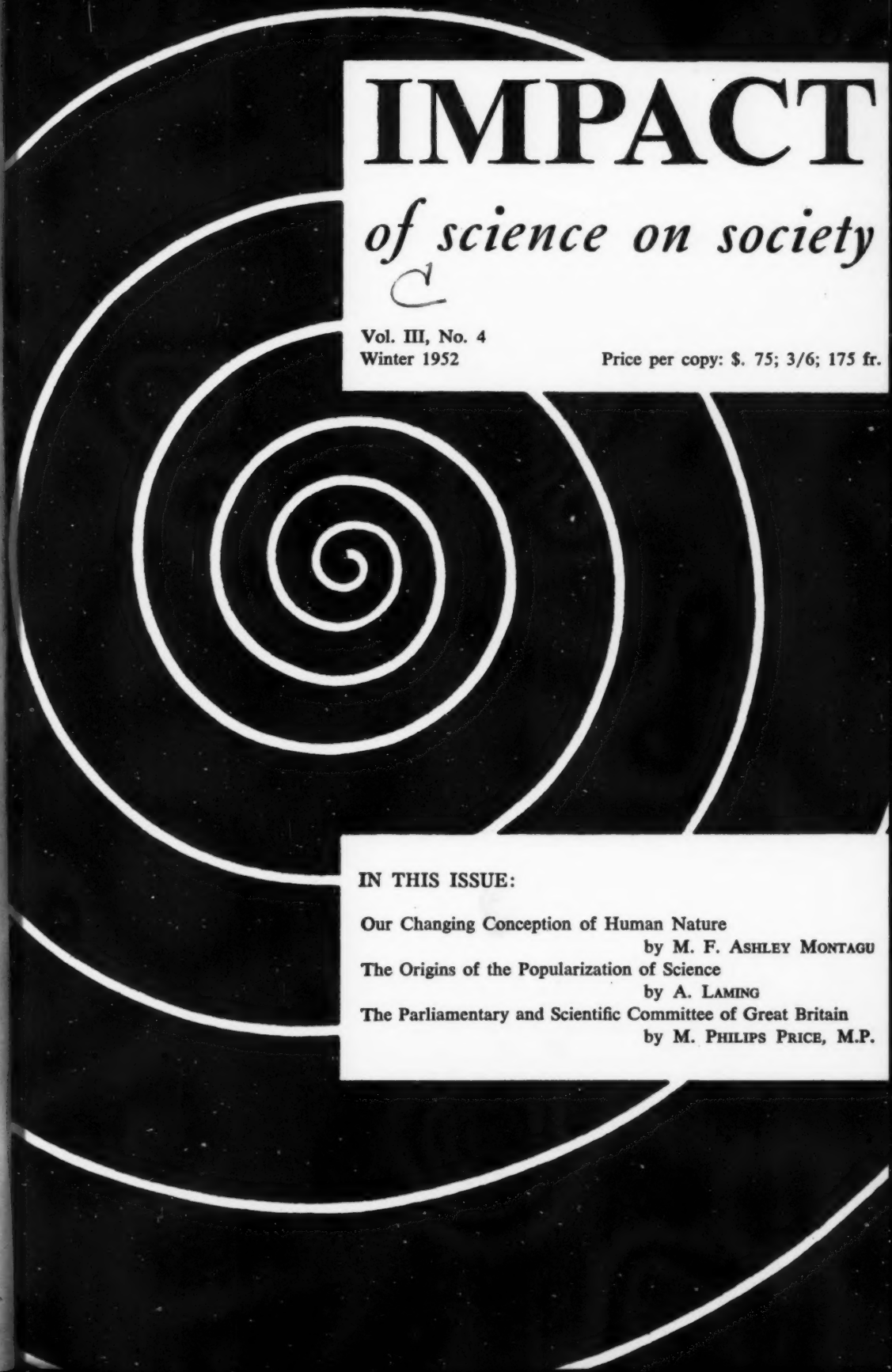

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OUR CHANGING CONCEPTION OF HUMAN NATURE

by

M. F. ASHLEY MONTAGU

M. F. Ashley Montagu is Professor of Anthropology at Rutgers University, U.S.A., and Associate Editor of Isis; *he is the author of several books on physical and social anthropology, some of which are included in the bibliography at the end of this article.*

Theories on human nature have been as numerous as the proverbial leaves of Vallombrosa, but it was not until the beginning of the twentieth century that human nature became a subject of serious scientific study. This study has revealed a multiplicity of facts which neither the theologians nor the philosophers so much as surmised. The facts set out in this article, and their discussion, should serve as a challenge to social thinkers and the leaders of public opinion.

WHAT IS HUMAN NATURE?

The answer to this question is, of course, the purpose of this paper. Obviously "human nature" can mean several different but mutually reconcilable things at one and the same time, so that until we have explored these different meanings and reconciled them, it will not be possible to make a brief, valid and readily understandable statement as to the nature of human nature. However, it is possible to say several significant things about it at once.

First, then, it should be said that no organism of the species so prematurely named *Homo sapiens* is born with human nature. What human beings are born with is merely a complex of potentialities. Being human is not a status *with* which but *to* which one is born. Being human must be learned. This is an important distinction, for the age-old belief in the innate nature of human nature has been responsible for much personal, social, and political misunderstanding, and for an untold amount of human suffering.

What are the specific qualities or characteristics, and what is the peculiar nature, of man that distinguish him from all other creatures? On the basis of his obvious physical characteristics man is described as a mammal of the order Primates, genus *Homo,* and species *sapiens.* But what of his psychological classification? While every creature that is classified physically as man is thereby called *Homo sapiens,* no such creature is really ***human***

until it exhibits the conduct characteristic of a human being. If it is true that one has to learn the kind of conduct that is uniquely human, then any organism which fails to learn that conduct cannot be human. In a sense this is a sound argument, and a closer examination of this argument will serve to throw much needed light upon the meaning of human nature.

The fact is that man is human by virtue of both his physical and his mental traits. In the course of his evolution the two appear to have gone hand in hand. One can no more deny the status of being human to a newborn baby because it cannot talk, than because it cannot walk erect. The wonderful thing about a baby is its promise, not its performance—a promise to perform under certain auspices. A juvenile ape can do a great deal more than can a juvenile human [1],[1] but the promise of the child far exceeds that of the brightest of apes.

Now, what is this promise? The answer is: a remarkable capacity for learning to use complex symbols and symbol relationships [2], a symbol being a meaning or value conferred by those who use it upon any thing. A sign, on the other hand, belongs to the physical world, it is a physical thing which indicates some other thing or event. A symbol belongs to the human world of meaning. Now, it is generally agreed that newborn babies are incapable of symbol usage; it is an ability which they have to learn; if they are not taught it they do not learn it.

We can thus say that human nature means the uniquely human set of *potentialities* for being human with which the organism *Homo sapiens* is born. *Potentialities* must be underscored, for what is generally erroneously assumed is that human beings are born with certain definite traits and characteristics which only need time if they are to develop, whereas the researches of the last 30 years have increasingly shown that the traits and characteristics of the organism will to a very large extent be determined by the kind of cultural stimulation which those potentialities receive.

What most persons have taken to be human nature, is actually the *acquired* behaviour of the person; this may and usually does become a second nature, and this, too, could be called human nature, since it is a function of man's nature in interaction with his environment, but it must not be confused with man's *inborn* nature—and this is exactly where the confusion is usually made. No doubt, since one always learns in a particular human environment, one's potentialities will develop according to the pattern of conditions to which they are exposed. Hence, human nature may express itself, or rather be made to express itself, in many different forms. But the differences in these forms are not, according to modern evidence, determined by innate factors but by environmental ones.

Man is born not with the ability to speak any language, but with a

1. The figures in brackets refer to the bibliography on pp. 231-32.

capacity or potentiality for speech, and this potentiality will never develop in the absence of the proper stimuli. These stimuli will usually assume a form determined by a particular environment, so that what the organism learns to speak will be of purely social origin, just as the way in which he learns to eat will be socially determined. Now languages, knives and forks, and fingers, are all instruments for manipulating one's environment, but whereas fingers are natural, languages and knives and forks are artificial. Obviously it is no part of the primary or innate nature of man to create artifacts. Science knows of no natural drive in man to make knives and forks or to speak Italian; Australian aborigines neither use knives or forks nor do they speak Italian, not because they couldn't do so, but because they happen to be born into a cultural environment from which such instruments are absent and where their own language alone is spoken.

In short, how a person will behave, what he will do, think, or say, what language he will say it in, and what artifacts he will prize, will be determined not by his innate nature so much as by his acquired experience. And this gives us the answer we have been seeking: human nature consists of the unique potentialities for complex symbol usage with which the organism is born, potentialities which undergo development within the matrix of a stimulating cultural environment, the emergent result being a human being, made to measure, and tailored to the prevailing cultural pattern in which he has been conditioned. The process of learning the traditional cultural patterns is called *socialization,* and is essentially cultural in character. We may, then, call the cultural endowment of human potentialities *primary human nature,* and the socialized development of those potentialities *secondary human nature.* Human nature, therefore, consists of both primary and secondary elements, the innate *and* the acquired. Where most errors have been committed in the past has been in the identification of the latter with the former.

While the primary human nature of all men is fundamentally similar, the secondary human nature frequently differs owing to differences in the history of cultural experience [3]. In short, human nature assumes secondary forms according to the pattern of the socialization process in which it has undergone development, and this pattern is determined by the cultural history of the group [4].

HUMAN NATURE BEGINS TO BE INFLUENCED AT FERTILIZATION

In the tradition of Western civilization it is the custom to reckon age as beginning from birth; other civilizations, notably the Chinese, reckon age as beginning from fertilization or conception. Accumulating recent researches indicate that this is scientifically a much sounder manner of reckoning age

than our own. The tendency to think of the child being born as a sort of *tabula rasa,* without a previous history, and beginning life, as it were, for the first time at birth, is wrong. The teaching in our scientific institutions hitherto has been that the fœtus *in utero* is so carefully protected, so thoroughly insulated from virtually all stimulations originating in the mother or the outside world, that it develops autochthonously according to its own inner resources and the nutriment which it receives through the placenta. It was and is still being widely taught that since there is no nervous connexion between mother and fœtus, the mother's nervous states could not possibly influence the development of the fœtus in any way.

With such a viewpoint concerning maternal-fœtal relations it is not to be wondered at that the prenatal period was considered irrelevant for the study of human nature. And yet nearly a century and a half ago a poet and thinker, Samuel Taylor Coleridge (1772-1834), wrote: "Yes—the history of a man for the nine months preceding his birth, would, probably, be far more interesting, and contain events of greater moment, than all the threescore and ten years that follow it." [5] It has taken science 150 years to come somewhere near supporting Coleridge's guess.

It is now a demonstrable fact that there is a very intimate connexion between the nervous system of both mother and fœtus; this connexion is established through what is increasingly coming to be known as the neurohumoral system. This system is composed of the interrelated nervous and endocrine systems acting through the fluid medium of the blood (and its oxygen and carbon-dioxide content) [6].

There is good evidence that an emotionally disturbed pregnant woman may communicate her emotional disturbance, at least in chemical form, to her fœtus. The Fels Institute workers at Antioch College, Yellow Springs, Ohio, have found that emotional disturbances in the pregnant mother produce a marked increase in the activity of the fœtus. They have also found that fatigue in the mother will produce hyperactivity in the fœtus; and that under severe emotional stress, especially during the later months of pregnancy, such mothers generally have babies who become hyperactive, irritable, squirming, feeding problems. Such an infant, says Sontag, "is to all intents and purposes a neurotic infant when he is born—the result of an unsatisfactory fœtal environment. In this instance he has not had to wait until childhood for a bad home situation or other cause to make him neurotic. It has been done for him before he has even seen the light of day". [7]

Not only this, there is evidence that the mother's emotional disturbances are reflected, through disturbances in nutrition, in the skeletal system of the fœtus [8]. It is, of course, not being suggested that the mother's emotional states as such are transmitted to the fœtus—this is almost certainly not the case. What does apparently occur is that the mother's emotional disturbance manifests itself in impulses which, passing from cortex to thalamus and

hypothalamus, proceed along the infundibulum to the pituitary gland. The latter then secretes various hormones directly into the blood stream which activates the glands of the rest of the body, and since most, if not all, of these hormones are of small enough molecular size, they will pass directly through the placenta into the fœtus, and there act upon it.

It is now well established that the fœtus is capable of responding to tactile stimuli, to vibrations, differences in pitch and tone, and to sound, to taste, and to various gases [9]. In other words, it is clear that far from being thoroughly insulated from the outside world, the fœtal organism is a great deal more sensitive to it than we ever suspected.

Even more important than these is Spelt's remarkable discovery that the human fœtus, *in utero,* during the last two months of gestation can be conditioned to respond to a paired stimulation of a vibrotactile conditioned stimulus and a loud noise as unconditioned stimulus [10]. This is the first successful experimental attempt to condition the human fœtus *in utero.* Evidently, the fœtus at seven months gestation age already has a sufficiently highly developed nervous system to be able to perform the operations necessary for learning.

Greenacre thinks that the evidence indicates the possible existence of pre-anxiety reactions in fœtal life without, necessarily, any psychic content [11]. She suggests that traumatic stimuli such as sudden sounds, vibrations, umbilical cord entanglements, and the like, including the "trip through the birth canal", may produce a predisposition to anxiety which, combined or not with constitutional traumatizing birth experiences, might be an important factor in the severity of any neurosis.

Without dwelling any further upon these facts, it should be reasonably clear that by the time a fœtus is born it is highly probable that the genetic structure of its potentialities for being human has already been more or less greatly influenced by the environment in which it has undergone development, and that hence, the primary human nature with which the organism *Homo sapiens* is born is not simply the genotypic potentialities as laid down at fertilization, but the more or less environmentally-modified expression of those potentialities.

Such facts and their understanding, it will be readily granted, are of the first importance for the improvement of human welfare. The care of the child should, of course, begin with conception, and the best way of caring for the developing human being is caring for the mother during and after her pregnancy.

HEREDITY AND ENVIRONMENT

Before proceeding further with the discussion, a few words must be said concerning the spurious dissociation between what is in fact only arbitrarily separable, namely, heredity and environment. Heredity is usually taken to mean the innate, i.e. the unadulterated biological inheritance of the organism as determined by the genes or hereditary particles in the chromosomes. This is usually referred to by geneticists as the *genotype;* the visible expression of the genotype is termed the *phenotype*. Now, the genotype always undergoes development within the complex medium of an environment, and the environment to a greater or lesser extent *always* influences the development of the phenotype. Hence, what the organism inherits is both the genotype and the environment which has formed it before birth. To disentangle what is due to genotype and what to environment, more especially where behavioural traits are concerned, is a task beset with unsolved difficulties. What is, however, clear is that behavioural traits are due to a combination of genotypic and environmental factors with, by and large, environmental factors playing a dominant role. This by no means excludes genotypic factors, but it does suggest, other things being equal, that insofar as behavioural traits in man are concerned, man's social heredity plays a more considerable role than does his physical heredity.

Since, then, the heredity of a person consists of the interactive effects of the innate potentialities for development within the environment, it follows that where we control environment we to some extent control heredity. This is an extremely important conclusion, for it tells us that the most effective way for human beings, for some time to come, to influence the expression of the genotype is through the environment. Heredity in the genotypic sense may determine what we can do, but environment determines what we do do [12].

CONSTITUTION

In view of the recrudescence of a constitutional school of human nature, which attempts to link man's behaviour to his physical traits [13], it is desirable here to say a few words concerning the conclusions reached by scientists with respect to the nature of constitution. Constitution may be defined as the sum total of the structural, functional, and psychological characters of the organism. It may be regarded as the integral of genetic potentialities influenced in varying degrees by internal and external environmental factors. Constitution is more properly regarded as a process than as an unchanging entity. It is not a biological entity, a structure predestined by its genotype to function in a predetermined manner. The manner in which

all genotypes function is determined by the interaction of the genotype with its environment.

All the relevant researches indicate that every genotype is a unique physico-chemical system comprising particular kinds of potentialities having definite limits. These limits vary from individual to individual, so that were the genotype to be exposed to identical environment conditions, its interactive expression would nevertheless continue to vary from individual to individual. In point of fact the environmental conditions are never the same for two individuals—a fact which renders it necessary for us to remember that heredity is not merely constituted by the genotype, but by the genotype as modified by the environment in which it has developed. The fact cannot be too often reiterated that what the organism inherits is a genotype *and* an environment: that heredity is the dynamic integral of both, the resultant of the dynamic interaction between the two.

Finally, it has become quite clear that genes, the heredity particles carried in the chromosomes, do not determine either character or traits; what they determine are the responses of the developing organism to the environment. The genes that the individual inherits are not, therefore, equivalent to predestination, but are amenable to the influences of the environment, and hence, to some extent, to human control.

Where the constitutionalists go wrong is in their claim that "structure determines function". Function is, of course, an aspect of structure, but as any elementary student of physiology should know, *the functions of structures assume their particular character according to the environment in which they operate* [14]. The constitutionalists consistently fail to understand the importance of the environment, especially in human development, and this is the most fatal of all the criticisms of their work.

WITH WHAT KIND OF BEHAVIOURAL EQUIPMENT IS MAN BORN?

It is generally agreed that man is born free of those biological predeterminants of behaviour which characterize other animals. Man is born without instincts [15], without those psychological dispositions which cause other animals to respond in a particular manner to a particular stimulus accompanied by a particular emotion. The form of the animal's responses is predetermined; man has to learn the forms which his responses assume. While other animals are mostly creatures of instinct, man is the creature of habit—the habit which he acquires from his culture. But these habits are organized by his culture around a number of urges, drives or basic needs, as they have been variously called. These terms are the merest labels for physiological conditions, the exact nature of which is far from being known.

There is fairly general agreement as to the number and definition of basic

needs. A basic need may be defined as a requirement of the organism which must be fulfilled if the organism and the group are to survive. The main basic needs are: oxygen-hunger, thirst, food, activity, rest, sleep, bowel and bladder elimination, sex, fear, and avoidance of pain. Malinowski has defined the concept of basic needs as "the environmental and biological conditions which must be fulfilled for the survival of the individual and the group" [4]. It is important to note that this definition includes the group as well as the individual, and this inclusion constitutes one of the most significant departures from, and improvement upon, the old concept of "instinct". It constitutes an explicit recognition of the fact that man, if not all other animals, functions, if he functions at all, in relation to a group; and that, so far as human beings are concerned, functioning, that is behaving, apart from a group simply does not occur. When human beings behave socially it means that they have been socialized within a human group—if they have not been socialized within a human group, then they do not behave like human beings.[1] Indeed, the person becomes related to himself to the extent to which he becomes related to the group [16].

Malinowski, who was the first anthropologist to attempt a comprehensive theory of needs, set out the permanent vital sequences, as he called them, which are incorporated in all cultures, in a list from which we shall take only one impulse, as follows:

(a) *Impulse,*	(b) *Act,*	(c) *Satisfaction,*
Hunger;	Ingestion of food;	Satiation.

This kind of sequence is rather too elementary and, in fact, unsound, because Malinowski has failed to perceive that the act leading to satiation (here in the case of hunger) is an indissoluble part of the process of satisfaction, and because there is rather more involved in the actual sequences than Malinowski's order suggests. A list of basic vital sequences prepared by the present writer follows.

1. There are no examples of completely isolated human children—in spite of many published accounts to the contrary—but there are several recorded cases of children who have been almost completely isolated from human contact for several years (these cases will be discussed in a book now in preparation by the author); such children fail almost completely to develop as human beings, and in many cases are even psychically blind and deaf, unable to walk or run, and unable to make more than the most elementary sounds.

Warning mechanism	*Physiological tension*	*Urge or need*	*Satisfaction*	
			Which leads to	*Homeostasis*
Accumulation of CO_2	Oxygen hunger	Intake air	Breathing	Oxygenation of tissues
Periodic gastric waves	Hunger	Ingest food	Ingesting food	Satiation
Dryness of mucous membranes	Thirst	Intake liquid	Intaking liquid	Quenching
?	Sex	Conjugate	Conjugation	Detumescence
Reduced organization	Fatigue	Rest	Resting	Restoration of muscular and nervous energy
Excess energy	Restlessness	Be active	Activity	Reduction of energy to equilibrium
?	Somnolence	Sleep	Sleeping	Awaking with restored energy
Tonic disturbance	Bladder pressure	Micturate	Micturation	Tension removal
Peristalsis	Colon pressure	Defecate	Defecation	Tension removal
Autonomic activity	Fright	Escape	Escaping from danger	Relaxation
?	Pain	Avoid	Avoidance	Return to normal state
	Internal excitation	Craving	Neuromuscular act	Equilibrium

The warning mechanism is a minimum physiological change which provides the organism with cues enabling it to anticipate the full effects of depletion or excess. Thus, we generally drink before we become conscious of intense thirst, and indulge in activity long before we feel any intense need for it, and we breathe long before we feel the phobic stir, which precedes each breath we take, so faintly that we do not normally notice it [17]. The warning mechanism or minimum physiological cue enables the organism to anticipate its needs before the latter become too disturbing. Forestalling behaviour therefore becomes possible [18]. We are warned long before there is any tissue depletion or experience of excess. The intervals between the warning activity and biochemical depletion or excess vary, the margin of safety varying from a few seconds in respiration to hours in water balance.

The greater the interval the longer are the psychological complications which can be developed. The extent to which psychological processes can influence the various warning mechanisms varies widely.

Since the warning mechanisms operate through a phobic-like anxiety, failure to obtain the necessary satisfaction of the need which develops serves to increase anxiety; as Kubie remarks, every basic need functions between the pressure of "normal phobic and normal compulsive psychologic processes which are the Anlage of all pathologic distortions" [17].

Under certain conditions the warning mechanism and the basic need may become detached from one another; the warning mechanism in the form of a sense of dryness, for example, may continue to operate even though the tissues are thoroughly hydrated. Or vice versa, there may be a considerable degree of dehydration without any sense of dryness or thirst. Such dissociations are usually pathological. Anorexia or chronic lack of appetite is a well-known example.

One of the prevailing myths of our Western tradition is the belief that the baby is born inheriting something of the ancestry of its lowly forbears, with respect not only to its physical but also to its psychological traits. The alleged "aggressiveness" of animal nature, it has been held, is in part inherited by the young *Homo sapiens*. Freudian and Jungian psychology assumes the innate aggressiveness of man, and civilization is regarded by both as a more or less unsuccessful attempt to keep this innate aggressiveness within bounds [19].

Freud's postulation of a "death instinct" is now generally discredited, but his use of the synonymous term, "the destructive instinct", still plays a considerable role in psycho-analytically influenced writings. This alleged "destructiveness" is identified with man's alleged inherited aggressiveness, and so one of the dominant views about human nature in our own day has become associated with the belief that man is inherently born aggressive.

For this viewpoint there is not a shred of supporting evidence. On the contrary, *all* the available evidence gathered by competent investigators indicates that man is born without any aggressiveness within him whatsoever. Professor Lauretta Bender, through whose hands have passed literally thousands of children, in her capacity as a child psychiatrist finds that, far from being inborn, hostility in the child "is a symptom complex resulting from deprivations which are caused by developmental discrepancies in the total personality structure, such that the constructive patterned drives for action in the child find inadequate means of satisfaction and result in amplification and disorganization of the drives into hostile or destructive aggression". "The child," she writes, "acts as though there were an inherent awareness of his needs and there is thus the expectation of having them met. A failure in this regard is a deprivation and leads to frustration and a reactive aggressive response." [20]

Indeed, the development of the organism is toward maturation in terms of co-operation. Bender calls it "the inherent capacity or drive for normality". And she adds: "The emphasis on the inborn or instinctive features of hostility, aggression, death wishes, and the negative emotional experiences represent a one-sided approach which has led our students of child psychology astray."

Professor Abraham Maslow makes much the same points in an important article. Maslow writes: "Those human impulses which have seemed throughout our history to be deepest, to be most instinctive and unchangeable, to be most widely spread throughout mankind, i.e., the impulses to hate, to be jealous, to be hostile, to be greedy, to be egoistic and selfish, are now being discovered more and more clearly to be acquired and *not* instinctive. They are almost certainly neurotic and sick reactions to bad situations, more specifically to frustrations of our truly basic and instinct-like needs and impulses." [21]

Professor Gardner Murphy writes: "As we watch behaviour in early childhood, we no longer assume that each individual will inevitably push himself ahead and crave every toy or every attention he can get; instead, we begin to ask if there is something in our society that does not satisfy the child's needs and, therefore, makes it aggressive." [22]

The fact seems to be that aggressiveness usually develops in the child as a result of frustration, that is to say, the blocking of expected satisfaction. The infant expects to have its needs satisfied; if those needs are not satisfied it feels frustrated, and normally reacts with aggressive behaviour. It is now coming to be understood that aggression is, in effect, a technique or mode of compelling attention to, and satisfaction of, one's needs.[1] Such an interpretation of the meaning of aggressive behaviour in children puts a very different complexion upon the manner of handling it than has been customary in the past. Aggressive behaviour in all human beings most frequently represents a response to frustration [23]; a response to the frustration of expected satisfaction. In this connexion the work summarized in Ashley Montagu's *On Being Human* [24], and more recently in the WHO report by John Bowlby on *Maternal Care and Mental Health* [25], should be consulted.

As the result of the work of a large number of investigators (whose research will be found described in the two last-mentioned books) it is now indisputably clear that the satisfaction of the child's needs by the mother or some substitute for the mother is necessary for the healthy physical and mental development of the person. Physical satisfaction of the needs of the organism is not enough; what is necessary in addition is the warmth, the

1. I believe that the late Ian B. Suttie was the first to point this out in his important book, *The Origins of Love and Hate*, Kegan Paul, London, 1935. This book is, incidentally, perhaps the best and most original critique of Freudian psychoanalysis extant.

love of another human being who is deeply interested in the welfare of the child.

It is becoming increasingly clear that the infant is born not only with the need to be loved, but also with a need to love; he is certainly not born with any need to be aggressive.

This view of human nature makes a very different picture from the traditional one, with its conception of man born with an aggressiveness which the process of socialization must suppress or eradicate. It is that view which rendered rationalizations about the "innate warlikeness" of man, and facile generalizations about man as a "brute", the stock in trade of every former authority on human nature. But modern research has shown that this view of human nature is erroneous. Man is not born evil or aggressive—he is rendered so. This being the case, it is incumbent upon us to realize that we can best change human nature for the better not by working on man's biological inheritance but by working on his social inheritance: by changing those conditions which produce disharmony in the person and corresponding disharmony in his society. As Professor Warder C. Allee has said: "Despite many known appearances to the contrary, human altruistic drives are as firmly based on an animal ancestry as is man himself. Our tendencies toward goodness, such as they are, are as innate as our tendencies toward intelligence; we could do well with more of both."

The school of evolutionary thought which preached the struggle for existence and the survival of the fittest gave a one-sided view of nature as a competitive "red in tooth and claw" process, and omitted almost entirely the factors of co-operation and mutual aid, which play so great a role in the ecology, the balance, of nature. The resulting view of nature was thus put badly out of focus, but upon it was erected a view of human nature which was as readily accepted as was the evolutionary theory of nature modelled on a *laissez faire* industrial civilization.

Perhaps one of the most important of our conclusions is that never was there a stereotype more unsound than that enshrined in the view: "You can't change human nature." On the contrary, we find that man is the most plastic, the most malleable, the most educable, of all living creatures; indeed, that educability is a species character of *Homo sapiens*. Man is the learning animal, and he is capable of learning and changing his views and his habits throughout his life.

Human nature, happily, is a great deal better in its promise than man has thus far realized in his performance.

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THE ORIGINS OF THE POPULARIZATION OF SCIENCE

by

A. LAMING

Mrs. A. Laming holds the degree of Licenciée ès Lettres *in philosophy. She worked for four years in the humanistic studies section of the French National Centre of Scientific Research. She edited the book* Découverte du passé *(Picard, Paris, 1952), which was written by a team of American, French and British authors and which deals with scientific methods of studying archæological and prehistoric remains.*

The influence of scientific progress on society makes itself felt in two separate directions. On the one hand, it generates a technical development whose innumerable applications are perhaps the most characteristic feature of modern societies and whose penetration of every field of activity has become a leading theme of contemporary thought. On the other hand, science exercises a less spectacular but equally fundamental influence on the society which gave it birth, an influence which, though not linked with the development of techniques, will often be fostered by it. It acts directly, that is to say, on the human minds with which it comes in contact, moulding their ideas, dictating to them a new view of the world and conditioning their political and social thinking, their tastes, their reading, sometimes their leisure and almost always their programmes of education. The scientific knowledge of a period permeates society with a certain scientific humanism characteristic of the age; it is a factor of its personality.

It modifies both the elements which make up a society and the ideas which dominate it. The scientific dilettanti of the seventeenth and eighteenth centuries and the bluestockings of the same period set the tone for an aspect of fashionable life just as popular science reviews and model clubs, for example, play a big part among the pastimes of a section of present-day youth. But though popular science may often be only a craze, it becomes a factor working for development and innovation, because it influences philosophers, writers, artists and politicians; all those, in fact, who think and act.

Today there is scarcely a social class in the Western world that is not imbued with at least some of the more general themes of science. Education on the one hand, and the press, cinema and radio, on the other, scatter them broadcast over the world. The actions they exert and the reactions to which they give rise have become extremely complex. Two or three centuries ago these forces were still quite new and pretty rudimentary, and their penetra-

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tion of the public mind took relatively simple forms which the passage of time only emphasizes. Popularization of science, a French invention, long remained a French monopoly. It was at the end of the reign of Louis XIV and the beginning of that of Louis XV, that is to say at the turn of the seventeenth and eighteenth centuries, that the first popular works appeared, and it was in the *salons* where the intellectual cream of Europe met and in the public lectures where aristocrats and poor students sat side by side, that we can detect the first signs and the first consequences of the dissemination of science among the public.

TRADITIONAL KNOWLEDGE AND POPULARIZATION OF SCIENCE

Popularization of science is of comparatively recent origin: Littré's dictionary of 1882 describes it as a neologism. But the idea preceded the term, and there is general agreement that Fontenelle's *Entretiens sur la pluralité des mondes*, which appeared in 1686, was the first work of popularization. This opinion, however, calls for certain comments. If we are to abide by the strict sense of the word, the idea of popularizing science, that is to say of disseminating the more accessible of scientific notions among the general public, is much later than Fontenelle. His works and those of the writers who followed him are intended essentially for the aristocracy and the wealthy upper middle class, and when they address themselves to women, it is ladies of the Court they have in mind. The story is told of Fontenelle that one day he declared for all the Café Procope, seventeenth-century Paris's intellectual snob centre, to hear: "If my hand were cram full of knowledge, I wouldn't open it for the people." And in the sixth evening of his *Entretiens* he has no hesitation in advising the charming marquise he is teaching: "Let us content ourselves with being a select little band and not disclose our mysteries to the people." Odd language, surely, from the "father of popular science"!

In fact, popularization down to the level of the general public was not known till after the French Revolution; economic and social conditions precluded it. And when it did come, its development was slow, for there was no question of publications which had been catering for fashionable circles extending their appeal overnight to a new readership. The generation which was 20 years old in 1789 and which reached maturity under the First Empire had received the upbringing of the old régime: some of its members retained their literary culture with a veneer of the new sciences, but the rest could not hope to acquire the rudiments of an education from which they had been debarred in their youth. We must jump a generation and come to the 1830's to see the public expanding on any real scale and beginning to draw recruits, though they might be rare ones, from the

working class or the new rich. This public had a fresh mind. It opened its arms wide to the enthusiasms of the age and felt an unbounded admiration for science and its future. It was moreover encouraged by the new techniques in the book trade and the press, and by the sudden expansion of their means of dissemination.[1]

The real popularization of science, the popularization that reached the people, did not then begin with Fontenelle and his age. On the other hand, the spread of a certain knowledge of science among the public dates back long before him. In a wider sense, as soon as there are schools and a curriculum of education, that is to say as far back as we can go in the history of our civilizations, there is popularization. Throughout the Middle Ages and for long afterwards, education remained essentially religious: it was the expression of a certain biblical conception of the world, its nature and its history. On top of this influence was superimposed the influence of the Aristotelian system, and though this was to a great degree a classroom affair, it overflowed the circle of students and reached a wider public.

The literature of the Middle Ages has a weakness for the encyclopaedic. The universe of Dante's Divine Comedy, with its spheres like Chinese boxes, with the earth, the realm of corruptible matter, at the centre, the whole set in motion by angels and spirits, is a sweeping cosmological system which draws its inspiration from Aristotle, Ptolemy and Christian ideas. The second part of the *Roman de la Rose* (1270), the most read of all mediaeval romances, contains digressions on the most varied subjects: philosophy, medicine, physics, astronomy and theology are all touched on. It thus gives a fair idea of the average knowledge of mediaeval man, and its influence survived the end of the Middle Ages, for an edition was printed as late as 1527. Didactic poetry was also a current form from the twelfth century on, and has bequeathed us bestiaries and lapidaries, besides a number of works of encyclopaedic type. The general ideas which were thus put into circulation, by word of mouth or by manuscript, among a fairly wide public covered the history of the world, the planetary system, the nature of matter and of living beings and their properties. In fact they played the same part, making due allowances, that the parallel ideas play among the public of today.

But abruptly, in the sixteenth, seventeenth and eighteenth centuries, scientific discoveries broke out of the framework of what had been taught up to then. The new systems of the world suddenly roused the curiosity of those who had enough leisure to think, namely, aristocrats and the educated middle class. At the beginning these systems, those of Copernicus and

1. On the living conditions and leisure of the different social classes in France under the old régime and in the nineteenth century, see Jean Fourastié, *Machinisme et bien-être*, Les Editions de Minuit, Paris, 1951. On the new public and the new press techniques in the nineteenth century, see A. Thibaudet, *Histoire de la littérature française de 1789 à nos jours*, Stock, Paris, 1936.

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Galileo for instance, were more or less accepted side by side with the old Biblical conceptions. Then little by little they took their place. The necessary adjustments were easier in the case of problems of physics or astronomy, more difficult as the subject was nearer to problems of life and human nature. The adaptation took a long time but little by little the new systems of the world integrated themselves into the everyday ideas of the seventeenth and eighteenth centuries. The idea of evolution had to await the end of the nineteenth century before it was taken as a matter of course. As to the nature of life and of the human faculties, it would be very hard even today to give a definition of them that everyone would accept.

The members of a coherent society always get to know in some way or other the fundamental postulates of its thinkers, though the time lag may be considerable. They always receive through some sort of channel the groundings of religious or scientific knowledge. No knowledge has ever been really esoteric. And, however elementary may be the means of communicating these ideas, they always end by permeating the cultural atmosphere of society, for all they may become corrupted as they get farther from their points of origin. Little by little what started by being a novelty and called for popularization becomes traditional knowledge and a part of teaching.

With these reservations, whose only aim is to reduce to its proper proportions the influence of the facts we are about to discuss, it remains true that the seventeenth and eighteenth centuries marked a crucial point in the history of popularization. The upheaval in almost every field of human knowledge and the favourable economic and social conditions led to its sudden blossoming in the upper classes of the period.

SCIENTIFIC PROGRESS IN THE SIXTEENTH, SEVENTEENTH AND EIGHTEENTH CENTURIES [1]

The sixteenth century, the century of scholars, employed the first ardours of its thirst for knowledge in rediscovering the science of antiquity, which had in great part been lost during the long scientific darkness of the Middle Ages. It edited it, annotated it, assimilated it, and this science could from then on serve as a starting point for further researches and save Western thought the pains of retracing the long road already covered by the scientists of Greece. By the middle of the sixteenth century this preliminary work was finished, and philology could give way to direct research. The latter was to discover or to improve the two methods which are the basis of all modern science, the mathematical method and the experimental method.

1. For the development of the sciences in Western thought from the Renaissance on, see Herbert Butterfield, *The Origins of Modern Science*, Bell, London, 1949, and the Macmillan Company, New York, 1951.

The progress of mathematics and its application to the physical sciences are essential points in the history of the scientific development which followed the Renaissance. The advance was in all directions. It is sufficient to recall that Kepler had the advantage over the astronomers who preceded him of a solid mathematical learning, that the name of Descartes is linked with the invention of analytical geometry and those of Leibnitz and Newton with that of the infinitesimal calculus. One improvement after another was meanwhile introduced into the handling of the mathematical instrument: for the first time letters were employed to represent magnitudes, new symbols were found, the decimal system was employed for the representation of fractions, and various arithmetical operations were simplified. The instrument became easier to handle, and, above all, men began to realize its importance for the study of the physical world. Galileo maintained that the book of the universe was written in mathematical language, Kepler that the mind is made to study quantities. And Descartes' matter, reduced to its mathematical qualities, is a very long way indeed from the Aristotelian essences.

The importance of the experimental method took longer to assert itself. Experiments were certainly not unknown in the Middle Ages, as is shown by the extraordinary laboratories of the alchemists. But experiments ranked below authority. It is only in the seventeenth century that the idea of seeking proofs of a theory in experiment began to gain ground. The creation of scientific instruments encouraged this new turn in research. The telescope and the microscope appeared at the beginning of the seventeenth century, the barometer and the thermometer a little later. The improvement of techniques in the working of glass and metal had immediate repercussions on that of laboratory material. Of all the instruments put at the disposal of research workers, the microscope and the telescope were to play the biggest part in the spreading of the sciences outside the circle of specialists. They were easy to handle and the revelations they brought with them were spectacular; they were to familiarize the minds with changes of scale, to give them an idea of the infinitely large as well as of the infinitely small.

Finally it should be added that contacts between scholars were becoming easier and more frequent. From the end of the fifteenth century on, printing shops had been springing up like mushrooms in every intellectual capital. Books, printed on rag paper, were accessible to scholars, and the invention of wood and copper engraving allowed them to be illustrated, an advance of key importance in the descriptive sciences. Moreover, means of communication had become more regular, and the post in particular had been considerably improved. It became possible for a regular correspondence to be maintained between the different countries of Europe. In France, a fixed charge was instituted in 1627 for the carriage of letters, and despatch offices were organized in the principal towns. In 1653, Mazarin introduced "carriage paid tickets", which were a sort of postage stamps. There were at

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that time two mails a week from Paris to the principal towns of the kingdom, and a letter took only five days to go from Paris to Marseilles.[1] In these circumstances correspondence between scientists became easy and developed on a considerable scale. Academies like the Royal Society in England and the Academy of Sciences in France reinforced these links.

The scientific movement born of the Renaissance penetrated into every field, first into astronomy and physics, later into the sciences of nature and of life.

In the history of science, every inventor has so many predecessors and disciples that the contribution of his genius seems sometimes to become diluted with ideas which he did not discover. All the same, it can be said symbolically that Copernicus, a Pole, and Galileo, an Italian, began the series of discoveries which were to revolutionize the cosmic system. Copernicus substituted for the old view of the universe—as a series of concentric spheres enclosed one within the other, with the earth as their centre—a universe in which the sun replaced the earth as the centre of the world. Henceforth it was round the sun that the planets revolved, and already the question was raised whether in this incommensurable world there might not be other inhabited stars. For having seriously maintained it, with many other daring hypotheses, Giordano Bruno was burned as a heretic in the year 1600.

Galileo adopted the Copernican system. He discovered the laws of falling bodies, demonstrated the rotation of the earth and in 1609 made in Venice an astronomical telescope with which he was able to carry out a whole series of new observations of the moon. Despite his condemnation, the influence of Galileo was rapid and final. The rotation of the earth on its axis was an idea hard to drive home, and a scientist such as Mersenne, though a great admirer of Galileo, was not convinced by the demonstration. But the exposition of the Galilean system as a whole had opened the way to a whole chain of discoveries about movement, on the earth as well as in the heavens. In 1687, the publication of Newton's *Principia* and the theory of universal gravity marked its culmination. The successive solutions put forward by the scientists, by turning the traditional system of the universe upside down, aroused an extraordinary current of curiosity among the public.

As regards knowledge of the functions of the human body, the revolution is almost contemporary. There, as with physics and astronomy, it was the University of Padua which set the pace. A work of Vesalius which appeared in 1543, the year Copernicus published his *De Revolutionibus Orbium,* marked a big advance in knowledge of the circulation of the blood and brought anatomy into fashion. Despite the stubborn opposition of traditional medicine, anatomy continued to progress in the sixteenth century, and in

1. G. Brunel, *La poste à Paris depuis sa création jusqu'à nos jours,* Amiens, 1920.

1628 William Harvey, who had also studied at Padua, gave a complete description of the circulatory system and of the relations of the heart and the lungs. The only thing that escaped him was the connexion of the arterial system with the veinous system through the capillaries, which was to be discovered by Malpighi in 1661, thanks to the use of the microscope. With Harvey, the study of the human body had entered a new phase: each organ was considered as a piece of a mechanism whose working it was the aim of science to understand. In 1637, this new theory was expounded at length by Descartes in his *Discours de la méthode* and became available to the educated public.

If the new system of the world was the work of the seventeenth century, the modern conception of the constituent elements of matter was that of its successor. The Renaissance had left intact the four elements of Aristotle, fire, air, earth and water. But the combination of these four elements was far from accounting for all the chemical phenomena even then known. It was round the phenomena of combustion that the experiments centred which permitted the first discoveries to be made. In 1731 a German, Stahl, developed the theory of "phlogiston", a substance which escapes from bodies at the moment of their combustion. At the same time it began to be suspected that air was not a simple element, but was composed of different gases. The work of Black, of Scheele and Cavendish were the milestones in the eighteenth century that preceded the decisive experiments of Priestley and of Lavoisier. Priestley in 1774 succeeded in isolating oxygen, which he called "dephlogisticated air", and Lavoisier a few years later demolished the phlogiston theory by discovering the part played by oxygen in combustion and by showing that water is not a simple element, but can be decomposed into and recomposed from its elements. Lavoisier also discovered the fact that organic bodies are composed of carbon, oxygen and hydrogen, and laid the bases of a chemical terminology which to a large extent is still in use today. The breaking down of matter into simple elements with specific properties marks the beginning of modern chemistry. It came later than the period of which we are speaking, but the experiments that paved the way for it were enthusiastically followed by public opinion throughout the first half of the eighteenth century.[1]

There remain the natural sciences.[2] The work carried out on this subject in the classical world had been for the most part descriptive and had not got beyond a rudimentary stage. The scientists of antiquity had been acquainted with numerous minerals, but had not attempted to classify them. They were also familiar with many species of plants, which they often used medicinally, but they were too apt to attribute fabulous properties to them,

1. Butterfield, op. cit., Chapter 11, pp. 150-63; Maurice Dumas, *Lavoisier*, Gallimard, Paris, 1941.
2. For the beginnings of the natural sciences see Cuvier's monumental *Histoire des sciences naturelles*, Paris, 5 volumes, 1841.

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as also to certain species of animals. Aristotle had sketched the main divisions of the animal kingdom, but his successors never subdivided these genera into classes or species. Besides this absence of a system of classification, which remained to be discovered, other gaps, of a technical kind, for a long time resisted any development of the natural sciences. Description without illustration is hardly ever sufficient, and the works illustrated with engraved plates which appeared in the course of the sixteenth century were the first solid basis for discussion and improvement. Inability to communicate a reproduction of the object described was for a long time accompanied by inability to preserve the object itself. Minerals and shells, which call for no special trouble to keep, constituted the first natural history collections, but the use of alcohol, the practices of embalming, stuffing or curing were only acquired gradually.

The discovery of America came as an unexpected spur to the development of the natural sciences. It aroused renewed curiosity in the wonders of nature. There was hardly a voyage to which some scholar or dilettante, anxious to study this unknown world on the spot, did not attach himself, and when they returned, their stories went the round, for the benefit of scientists as well as of the curious. Everything was new there, plants, animals and even the order of certain strata of the earth. From the very start the first mineralogists included descriptions of these faraway curiosities in their books.

Mineralogy was indeed the first of the natural sciences to take form. Works on fossils are numerous in the sixteenth century, and as the word fossil was used to cover everything that was dug up from the ground (from *fodere,* to dig) whether it was organic or inorganic, these books covered a lot of ground. The *De Re metallica* of Georgius Agricola, in 1546, represented a first attempt at the classification of minerals and was to serve as a basis for every work of the same kind down to the eighteenth century. In France, Bernard Palissy was the pioneer of mineralogical studies. Following the Italians, he maintained that the fossil shells often found on hillsides are the remains of marine animals. This was a somewhat revolutionary assertion, for fossils were generally regarded as "sports of nature", and the most fantastic explanations of them continued to be given for many years longer, right down to the middle of the eighteenth century. It is worth while quoting for its oddity the theory offered by Langy, Professor of Philosophy at Lucerne, who believed that fossils were generated by the lost sperm of living beings, carried by subterranean canals to the tops of mountains and there fecundated by the snow.[1]

The first correct explanations of fossils had a considerable influence. The domain of the historian, which had been confined to the Bible and the

1. Daniel Mornet, *Les sciences de la nature au XVIII^e siècle,* A. Colin, Paris, 1911, p. 20 *et seq.*

histories of the nations, was now to be extended to the history of the world and of living beings. Once the organic nature of fossils was accepted, other problems arose. The creation of the world in seven days and the sudden destruction of all land animals by the Flood could not explain the superimposed layers of fossils and still less the existence of fossil fish. Little by little it began to be suspected that the days of the Bible were not days of 24 hours, and that the creation was perhaps not as simple as had once been believed. Accompanying their better understanding of fossils, scientists sought for a satisfactory explanation of the superimposition of the strata of the globe, and began to suspect that its age was lost in the mists of a dizzying antiquity. By the end of the seventeenth century, this idea of the superimposition of strata was accepted. By the end of the eighteenth the study of fossil mammals was begun, and it was observed that the older the strata in which they were found, the more their characteristics differed from those of living mammals. Finally in the nineteenth century the basic notion of evolution was attained. For the old picture of a world created once for all and a human race with immutable physiological and psychological characteristics there was substituted that of a world in perpetual renewal and of a human race and a society continuously evolving. The first traces of this new outlook on history can be found during the Renaissance, but it was the eighteenth century, as we shall see, that first broadcast it among the educated public and drew from it its first philosophical and political implications.

The classification of minerals and fossils, that is to say the history of the world and its inhabitants, was accompanied by the study of the living beings who populate it. Zoological and botanical knowledge, however, were to remain for a long time yet in the stage of simple description and classification. Before pushing research work further, it was necessary to find a convenient framework into which the innumerable facts accumulated by travellers and naturalists could be fitted. This was to be the work of the eighteenth century, of Tournefort, Réaumur and above all of Linnaeus.

A final point about this scientific ferment of the sixteenth, seventeenth and eighteenth centuries was that understanding of contemporary man was also growing deeper and wider. From the historical angle, it continued to be centred chiefly on classical antiquity and the Bible. It took a long time, for Darwin had yet to arrive, to establish the connexion between animal evolution and human evolution. To the very end of the eighteenth century, no one suspected the antiquity of the origins of man and the biblical chronology was accepted more or less without question. The hypothesis of a pre-Adamic man, which dates from the middle of the seventeenth century, was abandoned after it had been condemned, and the discovery of an age of shaped stone which preceded the knowledge of metals did not come till a century later. But the discovery of the primitive civilizations of America was a revelation for Western thought. For a time men hesitated to credit these

savages with souls. Their customs, their languages, their beliefs and above all their religions created astonishment. It was, however, through these savages that Western man became aware of the relativity of his civilizations and of their values. He was to find in them the elements of a psychological and sociological science of man which was no longer to be confined to the grown-up, civilized and reasonable white man. It took some centuries for this consciousness to be acquired, but the question of the "savages" is often touched on by thinkers and philosophers, from Montaigne to Rousseau and the Encyplopaedists.

One or two key facts stand out from this rapid survey, which is necessary if we are to appreciate what were the ideas that from the Renaissance on began to be disseminated among the public and to superimpose themselves on the traditional views. The seventeenth century was the century of mathematics, physics and astronomy, the eighteenth that of the chemical sciences. As for the natural sciences, whose study was started in the sixteenth and seventeenth centuries, it was in the eighteenth century that their great development began. On another plane, the curiosity of the public was drawn in turn to one or other of these poles of attraction, while at a profounder level the conception of man and of his place in the universe, and of the nature of human societies, underwent modification and revision with each new discovery.

DISSEMINATION OF SCIENCE

With this hastily sketched outline to help us, we can now enquire what were the beginnings of scientific popularization in France under the reigns of Louis XIV (1643-1715) and of Louis XV (1715-74). The newly acquired general ideas were brought to the knowledge of the aristocracy and the middle class through different channels, which we shall now rapidly review.

Education

Education is not popularization, at least it is only a very particular aspect of it. And yet the curiosity and the assimilative capacity of a given public depend more than anything else on its education. In the middle of the seventeenth century, the education of a well-read man was essentially a philosophical and literary one. The encyclopaedic ideal of Rabelais had been stifled by an inordinate devotion to the classics, and the greater part of a young man's school years was taken up with the learning of Latin and the critical reading of the authors of classical antiquity. Things went so far that in the Jesuit colleges, for example, Latin was taught to the detriment of French: the classes were held in Latin and the children were obliged to talk

Latin among themselves. Religious training naturally occupied a big place, and only expurgated texts were put into the hands of the pupils. The curriculum ended with a two-year course in philosophy, which included logic, ethics, metaphysics and, in the final year, physics. This last subject was, however, treated from a largely philosophic angle. Science and mathematics teaching amounted to very little in the curriculum taken as a whole, yet quite a number of the great minds of the seventeenth century, including Descartes, Bossuet, Corneille, Molière and Fontenelle, received nothing but this very inadequate education.

The curricula offered by the Oratorians were more modern, but then the order had only been founded in 1611, whereas the Jesuit colleges had existed since the middle of the sixteenth century. French was taught there, and room was found for a certain amount of history and science. At Port Royal, whose "little schools", with their outstanding reputation, were founded in 1643, Spanish and Italian were taught alongside Greek and French and among the textbooks specially written for the Port Royal pupils is the *Nouveaux éléments de géométrie,* the work of the great Arnauld. Finally, in the university colleges, which were finding it hard to shed an outworn tradition, the philosophy class amounted to little more than commentaries on Aristotle, while there was no provision for any teaching of history or science.

As to the education of girls, it was essentially designed to turn them into God-fearing, obedient and virtuous women. Even the most ardent defenders of a more advanced education for women were still extraordinarily timid in the drawing up of their curricula at the end of the century. "Keep girls within the old-time limits," wrote Fénelon, "and make them realize that their sex should observe almost as great a modesty towards science as that which the horrors of vice inspire in it." Fleury again, who was another innovator in this field, excluded from his curriculum almost everything that was taught in boys' colleges. "It will probably be regarded as a great paradox to suggest that women should learn anything beyond their catechism, sewing and various minor accomplishments, such as dancing, singing and dressing in the fashion, dropping a graceful curtsey and making polite conversation, for this, in general, forms the sum total of their education! It is true that most of them have no need of the knowledge today included under the head ef education; neither Latin nor Greek, neither rhetoric nor philosophy taught in the colleges are of any use to them, and if some women with more curiosity than their sisters have tried to learn them, the only profit most of them have got out of it has been vanity, which has rendered them odious to other women and contemptible to men. . . . They can do without the whole of the rest of education, Latin and the other languages, history, mathematics, poetry and all the other curiosities."

The same general tendencies that prevail in the education given in the

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colleges are to be found in the curricula of the royal princes, with the same disproportion between literary and philosophic studies and scientific subjects. However, other tutors begin to appear alongside the head tutor, who is always responsible for Latin and the classical authors, history, grammar, rhetoric, logic, ethics and so on. For example Bossuet, who was tutor to the Dauphin from 1670 to 1680, calls in a mathematician, two physicists and even an anatomy master to assist him in his job. In 1684, when La Bruyère became tutor to the Duke of Bourbon, grandson of Condé, he was assisted by a young mathematics master. The day of the single tutor was past.[1]

One proviso should, however, be made. Scientific education was perhaps less neglected in the seventeenth century than a bare recital of the curricula would lead one to believe. Almost any branch of human knowledge can pass under the heading of philosophy, and in the last resort the curriculum of the philosophy classes depended much more on the knowledge of the master than on the designation of the class. The idea of introducing experiments in physics and chemistry into education dates from the beginning of the eighteenth century, but there can be no doubt that even when there were no science classes, the pupils of most of the colleges were kept in contact, by their philosophy masters, with the latest advances in astronomy, physics or anatomy. The philosophy master of Monsieur Jourdain has no hesitation in offering to teach him physics and to explain to him "the principles of natural things, and the properties of bodies . . . the nature of the elements, the metals, minerals, stones, plants and animals . . . the causes of all the meteors, rainbows, wildfire, comets, lightning, thunder, thunderbolts, rain, snow, hail and whirlwinds".

In higher education, there was a certain diversity. The three faculties of the University of Paris, where medicine, law and theology were taught, were still impregnated with the mediaeval spirit and hostile to any novelty. No science teaching was provided, which meant that they were very much behind the Italian universities. But the university had no monopoly of higher education. In order to counteract its conservatism, Francis I had in 1530, on Budé's advice, established the Collège Royal, later to become the Collège de France. Alongside Greek, Hebrew and Latin, chairs of medicine, philosophy and mathematics had been founded there by the middle of the sixteenth century. In the second half of the sixteenth century, Charles IX introduced surgery there, Henri III Arabic, and Henry IV botany and astronomy.

Another scientific establishment was to assume a growing importance from

1. On education in the seventeenth century see Braunschvicg, *Littérature étudiée dans les textes*, A. Colin, Paris, 1920, I, Chapter XXIII, "Les éducateurs", pp. 720-71; G. Compayré, *Histoire critique des doctrines de l'éducation en France*, Hachette, Paris, 1879; Lantoine, *Histoire de l'enseignement secondaire en France au XVII^e siècle*, Paris, 1874.

the middle of the seventeenth century. In 1635, two doctors attached to the household of Louis XIII received authorization by letters patent to found a botanical gardens where all the known medicinal plants should be assembled. In a very short time, the subjects covered outran the original plan, and despite the lively opposition of the faculty of medicine, chairs of botany, chemistry and natural history were founded there.

Thus the seventeenth century saw the establishment of a whole system of higher scientific training, thanks to which there came into existence little by little an educated and enquiring public possessing a certain scientific background. Some of the young people who followed it would continue their career as apothecaries, doctors or professors; if they had the means, they would perhaps devote themselves to research. They swelled the number of scientists and aspiring scientists, and perhaps contributed their mite to the scientific movement. The rest, who had only attended a few lectures in astronomy and anatomy out of curiosity or by accident, entered the profession their family had chosen for them. Often relegated to some distant provincial town, they would form, with the former pupils of the colleges and with a section of the aristocracy, the main body of those to whom the first works of popularization were addressed. They wanted to be kept posted in the latest novelties, and their wives and daughters often plumed themselves on the same curiosity.

Public lectures

The official scientific teaching, for all its development, was insufficient to satisfy either the thirst for learning or that for tuition. A host of public lectures came into being where theses that were sometimes extravagant and sometimes brilliant were expounded by professors who might be more or less learned but were generally hostile to the university.

In 1575, for instance, Bernard Palissy, "a plain potter", who knew neither Greek nor Latin, organized a series of lectures and discussions in which he had the audacity to defend, in French, theses contrary to those of the university. He expounded his ideas on the formation of stones and on their decomposition, as well as on the properties of many metals and other minerals: lead, tin, iron, antimony, litharge, manganese and so on. He supplemented his lectures by practical demonstrations which he carried out in the natural history collection, where right through his life he had amassed curiosities of every kind, principally fossils and stones. A fee was charged for admission to his lectures and demonstrations, which were very successful and went on for 10 years, and the prospectus which advertised them guaranteed the audience that they would get their money back fourfold if the things promised were not true. "But, thank God," wrote Palissy, "never a man said a single word to contradict me."

The fashion of public lectures continued to spread throughout the seventeenth century. There were those of Rohault (1620-75) who at the end of his life became tutor to the Dauphin and who in his lectures paid particular attention to supplementing rational proofs by experiments, and there were above all those of the celebrated Nicolas Lémery (1645-1715) in the rue Galande, which roused the enthusiasm of his audiences. His principal subjects were chemistry and geology, and with the aid of an ingenious apparatus which he had invented himself, and which was baptized "Lémery's volcano", he expounded and proved his theory of volcanoes and earthquakes. About the same period Guichard Duverney (1648-1730) and later Alexis Littré (1659-1725) started anatomy lectures in Paris and made this science fashionable. In 1701 Dagoumer, who was a professor at the University of Paris, invited the public to his experiments. In 1734 the Abbé Nollet, on his return from a scientific visit to England and Holland, organized a course of lectures in experimental physics which met with great success. Towards the middle of the eighteenth century, private lecture courses parallel with the official teaching sprang up like mushrooms.[1]

Their audiences were a heterogeneous collection. Into lecture rooms that were often small and uncomfortable crowded genuine scholars, young students, great noblemen, a few women, idlers, charlatans, country cousins on a visit to the capital and also many foreigners drawn by the scientific reputation of Paris. When the lectures were successful, the audience began to arrive long before the start and here and there could be seen a footman or two, come to reserve a place for their masters. These latter arrived later, maybe after the start, with a great commotion of horses and coaches, in a whirlwind of feathers and rich stuff. Fashion ordained it, and all that was fashionable in Paris met at the lectures of Lémery and the demonstrations of Duverney. When the lecture was over, the audience dispersed, but they were soon to meet again. A select party of scholars would go on to Varignon, the geometrician, who lived in the Faubourg St. Jacques, or Régis, the philosopher, or Le Hire, the astronomer; brilliant students and young disciples were often introduced to the masters, and a lot of foreign scientists were to be met there. As for the fashionable *salons,* they felt the influence of this craze, which supplied them with new topics of conversation and new interests. Between two madrigals, talk would turn to Descartes's vortices or the inhabitants of the moon. Scientists were accepted there regardless of their birth and sometimes this or that great nobleman would become a Maecenas.

1. Maurice Daumas, *Lavoisier, passim.*

Dilettanti and Collectors

This new taste for the sciences was displayed in yet another manner. The sixteenth century saw the start of a great number of public and private collections. The first such collections consisted mainly of minerals and of fossils. At the same time, scholars began to get together the first collections of antiquities, inscriptions found on ancient sites, medals, statues and so forth. These collections, which spread very rapidly, were not the work of specialists only. Provincial life offered few distractions, and many were the magistrates, doctors or officials who spent their leisure time collecting and ticketing whatever they found in the course of their outings. Those with literary tastes would have a preference for coins and fragments of marble, those with a scientific bent for minerals, petrified objects, rare plants or animals. But every type of exhibit was to be found jumbled together in the host of private collections which were springing up on every side. There would also often be objects from overseas, plants, animals or arms which had been brought back by travellers and for which collectors paid high prices. It would be impossible to find a person with any pretensions to education who had not had an opportunity of looking at one or two of these collections, the pride of their owners, who were delighted to throw them open to visitors and to explain. Moreover, an example was set by the highest quarters, for the royal collections were many, varied and extensive, and permission to visit them was readily granted.

Under the French monarchy, it was a time-honoured custom for travellers who returned from distant voyages to present the king with such curiosities as they might have found. Probably the earliest such rarities from foreign lands brought to France were the presents offered by Haroun al-Raschid to Charlemagne in the opening years of the ninth century. But it was not till the reign of Francis I that a special collection was organized to house the curiosities which the king ordered from every corner of the globe. Francis I took "a marvellous pleasure in the company of connynge men who had seen strange countries"; he had "nouelties" brought back to him from these distant lands, and these "nouelties" included not only manuscripts and objects of natural history but living animals, such as camels and a lion, and even Indians. These objects were housed in the various royal residences and became the foundation of the future public collections. We have no inventory of these old collections, but we know that they included such things as clothes and various objects brought back from Canada by Cartier, skins of birds, stuffed lizards and crocodiles, ostrich eggs and coconuts, medicinal plants, rare woods, unusual rocks and quantities of stone inscriptions, medals and other antiquities. After the return from Italy, medals and antiques were for some time the principal centre of interest in the Court, and two curators were appointed for the collections, one of whom was responsible for the

antiquities and one for the "singularities" of natural history. A certain Jean Mocquet, by virtue of his being an apothecary, was entrusted with the curatorship of the collection of "singularities". He was also a botanist and an embalmer and made a number of voyages to Morocco, the Guianas and Syria in order to add to the collections for which he was responsible. The principal objects he brought back were useful or remarkable plants (exotic woods, maize, potatoes and so on), drugs and fruits, minerals, shells and animals. On his return from each expedition, he would show his finds to the King and the Court and would spend hours explaining to them all he had seen and brought back.

Towards the middle of the seventeenth century, a little before astronomy and physics became the rage, the Court's craze for strange things from overseas was for a while forgotten in a passion for antiquities. Engraved stones, manuscripts and antiquities became the centre of interest, and the collections of "singularities" were scattered. Their function of arousing curiosity, however, remained alive and the tradition endured in the private collections of Paris and the provinces. It is not impossible that part of the royal natural history collections may have found a home in the Royal Garden, founded in 1635. This garden developed rapidly thanks to the interest of Colbert, and from 1739 on Buffon made big additions to it in the form of unusual skeletons and presentations received from every corner of the globe: plants sent from China by missionaries, a collection of minerals from the Polish Academy, gifts from Catherine II and so on. At the same period, the natural sciences became extraordinarily fashionable. Dilettante collections sprang up and catalogues were published of the exhibits whose rarity varied with the wealth or the extravagance of their owners.[1]

Popularization in Print

Side by side with the collections, libraries were springing up. The Royal Library, founded by Francis I and installed in the palace of Fontainebleau under the librarianship of Guillaume Budé, had 30,000 volumes added to it under Louis XIV, and the books on its shelves numbered 180,000 by the middle of the eighteenth century. From 1692 on, the Royal Library was thrown open to the public twice a week. On those days the Abbé de Louvois, who was the Royal Librarian, entertained scholars to a sumptuous meal, for the library was only used by students and by very scholarly men.

In the first half of the seventeenth century the public also had a new

1. For the private collections of the seventeenth and eighteenth centuries, see Charles Blanc, *Le trésor de la curiosité*, Paris, 1857-58, 2 volumes; Edmond Bonnafé, *Les collectionneurs de l'ancienne France*, Paris, 1873. For the origin of the royal collections, see Dr. T. Hamy, *Les origines du musée d'ethnographie*, Paris, 1890, Chapter I; F. H. Taylor, *The Taste of Angels, A History of Art Collections from Ramses to Napoleon*, Little, Brown and Co., Boston, 1948. For the old natural history collections, see Cuvier, *Histoire des sciences naturelles*, Paris, 1841, Volume I, Lesson 17.

means of information placed at its disposal. In 1631, the *Gazette* began to appear every week, while 1683 saw the foundation of the *Mercure galant*, which came out every three months. The *Gazette* was composed almost exclusively of diplomatic and military news, but the *Mercure* set out to keep the gentry posted in everything noteworthy that might have happened at Court or in town; its news on social events was rounded out with sermons, love poems and philosophic or scientific dissertations. The *Mercure galant* had many women readers. A little earlier, in 1665, a royal licence had authorized the foundation of a journal designed to "give information of every new event that occurs in the world of letters". It was known as the *Journal des savants* and was composed chiefly of abstracts of and extracts from new books and notices on celebrated authors. Twenty years later, in 1684, the *Nouvelles de la République des Lettres* started to appear in Holland, under the editorship of Bayle. It was a sort of counterpart of the *Journal des savants* with a similar public, chiefly men of letters and scientists, but also men of general education, and a new spirit of criticism breathed in its pages.

Apart from college education, no attempt was made by this little world of intense scientific curiosity to put at the disposal of the interested but non-specialized public, which was growing fast, the lectures, collections, libraries and journals whose principal aspects we have tried to outline. Many of this public, women in particular, had not received a trace of scientific education. All the same, carried away by the fashion of the age, they flocked to listen to the scientist of the moment, perused scientific papers and discussed vortices. Authors up to then had done little to bring science within the understanding of this public.[1]

It is true that the work of Gassendi, in Italy, written in a familiar style, was read far beyond the circle of astronomers and physicists, but this is a rare, if not a unique, case. In France eight editions of Olivier de Serres' *Théâtre de l'Agriculture*, which appeared in 1600, came out within 19 years, but this book, aimed to assist Henry IV's efforts for the revival of farming, was more technical than scientific. Mention must also be made of Descartes' *Discours de la méthode*, which on account of its being written in French and not in Latin and of the simplicity and clarity of its thought, found a public far wider than that of ordinary philosophical treatises. As for schoolbooks, which by their very nature are accessible to everyone, it would be a waste of time to mention them here; nobody has ever thought, any more today than in the past, of using them to satisfy his curiosity.

The first systematic written attempts at scientific popularization are due to Fontenelle. These works, which enjoyed a brilliant success, were penned

1. It should be noted that the writers of the seventeenth and even of the eighteenth centuries were not interested in big sales. The approval of those who knew the subject was all that mattered to them. A desire to make money was considered unworthy of a wit, and authors often gave their works to their booksellers.

on two different planes. The *Entretiens sur la pluralité des mondes* (1686) appealed to the public of the *salons* and to women; the *Eloges des académiciens* and the *Histoire de l'académie* were intended for a more learned type of reader. Fontenelle was led to embark on this latter kind of writing, in which he excelled, by the obligation laid on him as secretary of the Academy of Sciences to discourse on dead scholars and their works for the benefit of scholars of other specialities. He thus blazed the trail for two avenues of popularization: popularization for the learned public and popularization for ordinary people with a thirst for knowledege.

The *Entretiens* were intended for the public of the *salons* which he visited and where he was held in high regard. There was no one better qualified than he to gauge what this public liked, and the degree of attention of which it was capable. In the preface of the *Entretiens,* Fontenelle explains his aims very clearly. "My intention is to deal with philosophy," he writes—by philosophy he means principally astronomy and physics—"in the least philosophical manner possible; I have tried to develop it to a point where it shall neither be too dry for the gentry not too superficial for the scientists. . . .

". . . I should warn those readers of this book who have some knowledge of physics that I make no sort of pretension to instruct them, but only to entertain them by presenting in a rather more attractive and lively manner a subject with which they are already thoroughly acquainted. . . . I warn those to whom these topics are new, that I believe myself capable of instructing them and entertaining them at the same time. The former will thwart my purpose if they seek for profit here, the latter if they seek only for pleasure.

"I shall not waste my time saying that I have selected out of all philosophy the subject matter best calculated to stimulate their curiosity. It would be surprising if anything were capable of interesting us more than to know how this world we live in is made, if there are other similar worlds and whether they are inhabited too."

But Fontenelle knew the difficulties of what he was undertaking: ". . . People tell me . . . that such a work is suited neither to scientists, who will not be able to learn anything from it, nor to gentlefolk, who will not want to. . . . It may well be that in my attempt to find a middle course which shall make philosophy palatable to everyone, I have stumbled on a mean which makes it palatable to no one: middle courses are too difficult to hold, and I do not believe I shall ever feel any desire to put myself to the same trouble again." Fontenelle achieved a brilliant solution of the difficulty, which will always be the stumbling block of any work of popularization, and was able to preserve a golden mean between too much learning and not enough. His *Entretiens* enjoyed immense success, principally among women for whom they were particularly intended.

He did not stop there, and though none of his other works attained the

simplicity of style of the *Entretiens,* he continued to excel in the field of popularization. In 1694 appeared Thomas Corneille's *Dictionnaire des arts et des sciences.* Fontenelle, who was Corneille's nephew, had written, added to or revised a large number of the articles on mathematics and physics contained in it. But it was chiefly by his history of the Academy of Sciences that Fontenelle won fame in his own lifetime. He began it in 1699 and worked at it single-handed till 1739, which represents 40 volumes including extracts from unprinted papers, abstracts and obituary notices of his dead colleagues. "What the Academy needed," he wrote of Du Hamel, who had been his predecessor as its secretary, "was a secretary who understood and spoke fluently all the different languages of its scientists, that of a chemist, for example, and that of an astronomer. He must also serve as their common interpreter to the public and provide a mass of thorny and abstract subjects with elucidations, a certain style and even an attractiveness which authors sometimes neglect to give them but which most readers expect. Finally he must possess a character immune from partiality and therefore be capable of giving a disinterested account of academic controversies." What better definition could there be of a good popularizer and, through Du Hamel, of Fontenelle himself? The *Eloges* were read all over Europe, and as far away as Peru, where ladies were said to have learned French in order to read them.[1]

What Fontenelle and his *Entretiens* were for the system of the world the Abbé Pluche became some years later for the natural sciences. His *Spectacle de la nature,* which appeared in 1732, enjoyed an incredible success; it was translated into four languages and ran through 18 editions. About the same time Réaumur, who had already won fame by various papers, began the publication of his *Mémoire pour servir à l'histoire des insectes.* It was a revolution and a triumph. From the middle of the eighteenth century on, scientific popularization emerged from the stage of its early fumblings, and the success of the *Encyclopédie* may be taken as finally setting the seal on the new public taste for everything concerning the sciences and the techniques.

FROM SCIENTIFIC CRAZES TO THE PHILOSOPHIC REVOLUTION

We have examined the progress of the sciences in the seventeenth and eighteenth centuries and their means of dissemination among the French public of the period. We must now tackle the other side of popularization, that of the public, and enquire what kind of influence the new scientific discoveries had on it. We have seen that it is possible roughly to distinguish

1. On Fontenelle, see a study by M. Charma in the *Mémoires de l'académie de Caen,* 1847, pp. 225-318.

two stages in the scientific revolution: the first, which covers astronomy and physics, takes up the whole of the seventeenth century and is directly linked with the progress of mathematics; the second, which chiefly affects the chemical and natural sciences, is more dependent on observation and experiment. It is interesting to note that the public's crazes follow much the same line. Fontenelle's *Entretiens* date from 1686 and the Abbé Pluche's *Spectacle de la nature* from 1732.

Molière's comedies popularized the picture of learned women (they are middle-class women and not great ladies) who spent entire evenings in their attic trying with a long telescope to catch a glimpse of the inhabitants of the moon. Their entire conversation is dotted with atoms, animal spirits and subtle matter. It is highly probable that quite a number of men, the *nouveaux riches* of science, fell into the same sort of eccentricity, but they did not shock people so much and nobody talked of them. It should be noted that the *Femmes savantes* antedates the *Entretiens* by nearly 15 years, that is to say that what Fontenelle did was to sanction, not to create, the curiosity of an ever-growing public. In this case, the work of popularization was a response to a need, not the stimulus that called it into existence.

Soon this craze for astronomy, which up to the end of the seventeenth century was in direct competition with the passion for the ancients, their authors and their relics, was reinforced by a fever for the natural sciences. In 1687 La Bruyère, in his *Caractères,* pictures the various kinds of dilettanti. Some are mad about shells, others about insects, yet another about butterflies: he has got a collection of all sizes and colours and is plunged into the depths of misery when the most beautiful of his caterpillars dies. The counterpart of the learned ladies' telescope is the insect lovers' microscope; the antique collections of the seventeenth century are now paralleled by natural science collections. Every sort of rare insect and fossil is to be found in the shops. Gersaint's shop, on the Pont Notre-Dame, sells them in series whose price varies according to their size. They are advertised in the newspapers and in 1736 Gersaint even publishes a descriptive catalogue of fossils, a very scholarly document.[1]

The customers are the same as those who jostle each other at the better known lectures. There are scholars and men of letters from London, Paris and elsewhere, gentlefolk, ladies from high society, students and simple people too, all drawn by the new taste for science. You will see all the crowd that frequents the meetings of the Academy, that is to be found in the fashionable *salons* or that tries to drink coffee at the tables of the Procope. It would take pages to conjure up this curious society which, from the end of the seventeenth century to the end of the eighteenth, has found the secret of blending so elegantly the charm of the muses and the austerities of

1. Daniel Mornet, *Les sciences de la nature au XVIII^e siècle,* A. Colin, Paris, 1911.

science. The Comte de Caylus is undoubtedly one of its most outstanding successes, for after magnificent feats on the battlefield, he devoted his life to ladies, operettas, madrigals and his collection of antiques, and on top of all this first had the idea, among a thousand others, of making chemical analyses of mummies and of performing different experiments on the hardening of metals.

The influence of this charming half-scientific, half-social activity went deep. It was not merely a question of providing a pastime for idlers a little weary of their eternal gallantries. In the provinces, this activity encouraged the establishment of local academies; in Paris it played a part, and often a useful one, in the scientific movement, for it opened the doors of the *salons* to the scientists and enabled them to win the patronage and often the financial support of the great nobility. Above all, and this is perhaps the key point, it was little by little to unsettle traditional ways of thinking and to open an easier path for the new ideas of the eighteenth century.

Fontenelle's *Entretiens* are very instructive in this respect. They show in their simplest form the process by which the old certainties were destroyed and replaced by new ways of thinking, even at the level of people who, like the *marquise,* were far from being learned. Among these novelties, let us take the notion of a natural determinism, that of the relativity of human knowledge and the key idea of the indefinite progress of science. Let us then return to Fontenelle.

"In that case, said the marquise, philosophy has become very mechanical? —So mechanical, I replied, that I fear people will soon become ashamed of it. We are asked to believe that the universe is nothing more on a big scale than a watch is on a small, and that everything in it proceeds by uniform movements, which depend on arrangement of its parts. Now be frank. Have you not sometimes had a loftier idea of the universe, and have you not done it more honour than it deserved? I have seen people who have thought less of it since they began to understand it.—As for me, she replied, I think more of it now that I know it resembles a watch: it is surprising that the order of nature, wonderful though it is, turns on such simple things.—I do not know, I answered her, who has given you such sensible ideas; but to tell the truth it is not too common to have them. There are a lot of people who have got a bogus idea of the marvellous in their heads, wrapped up in an obscurity which they respect. They only wonder at nature because they believe it to be a sort of magic which is beyond comprehension; and you can be sure that a thing loses all prestige in their eyes as soon as it is capable of being understood." [1]

And the philosopher goes on. He explains to the marquise that the earth

1. *Entretiens,* First Evening.

is not the centre of the world as the Ptolemaic system had led people to believe. This was the first inroad on "the vanity of men, who had reserved themselves the best place in the universe".[1] A little later, in the second evening, this idea is further developed and that of the progress of science is asserted. "You will observe that little by little the world is expanding," says the philosopher. "The ancients were quite certain that the torrid zone and the glacial zones could not be inhabited, on account of the excessive heat or cold. . . . That did not prevent men from being discovered, both in very hot countries and in very cold ones, and there is the world already increased. Then it was laid down that the ocean covered the whole earth, except that part of it which was then known, and that there were no antipodeans, for nobody had ever heard speak of them and would they not have had their feet in the air and their heads downwards? Despite this impeccable reasoning the antipodes were discovered just the same, and there was a new alteration of the maps and a second half added to the earth. Mark me well, Madame, these antipodeans, who were discovered in the face of all expectations, ought to teach us to be less downright in our judgments. Perhaps one day the world will hold no more secrets for us, and we shall push our knowledge as far as the moon. We are not there yet, because we have not yet explored the whole globe, and apparently all this has got to be done in order. When we have got to know our own home thoroughly, we shall be allowed to learn about that of our neighbours, the people of the moon."

These are only one or two examples; it would be easy to find others in which the notions of natural laws and of determinism could be seen little by little replacing the old-time conception of a universe entirely subject to divine providence. And at this point the discussion takes on quite a new significance. It was not only charming and ignorant marquises who were influenced by the *Entretiens* and the works which followed. They affected every thinker, the cream of every class. They gave them a new picture of the world, of its laws and of its inhabitants; above all, they suggested new points of view and new rules of thinking and of action. The question is extremely complex, because what really happened was the complete overthrow of a whole system of thinking and of values, and the transition from one culture to another. It is, however, possible to distinguish within it two essential tendencies which, when they crystallized, resulted, in the field of action, in the French Revolution.

The ideas of progress and of scientific certainty led to a revision of the old notions of authority. The fact that the Church had supported theses which had been shown to be erroneous considerably shook its credit. Little by little the argument from tradition was replaced by that from scientific knowledge and verification. Despite numerous oratorical precautions, human

1. Ibid. First Evening.

knowledge began to count more than divine revelation. As one consequence, the power of the king, which was based on divine right, also lost its absolute character and became subject to discussion and revision. At the same time as this conversion of a world of authority and revelation into a world of experiment and discussion was proceeding, the first steps were being taken towards the application of the scientific method to the social and political sciences, and thus a more constructive point of view took its place alongside the critical and destructive consequences of the scientific revolution.

This invasion by science of every field of thought did not proceed without resistance. Throughout the ages the party of tradition and the party of progress have fought each other, but in modern times this struggle has been characterized by the appearance of a new set of arguments, that of the indefinite progress of science on the one hand, and on the other the retort about the evil effects of science, or at least its incapability of establishing the kingdom of heaven on earth. This is the eternal theme of the superiority of man in a state of nature over civilized man. In the seventeenth century this problem had come up almost entirely on the literary plane. The belief in the superiority of the ancients in every field of art and literature had been accepted since the Renaissance as almost the equivalent of a dogma, and from the outset the progress of the sciences and of mathematics had been regarded by many people with a certain suspicion. Blaise Pascal's father, who was a man of real education, wanted to prevent his son from studying mathematics all through his childhood, for fear he might later lose the taste for Latin and Greek.

The more the sciences developed, the more this anxiety grew in the camp of tradition. It led to publications such as that of the Abbé de Resnel entitled *Réflexions générales sur l'utilité des belles-lettres et sur les inconvénients du goût exclusif qui paraît s'établir en faveur des mathématiques et de la physique*. This suspicion was to be found even among the most progressive minds. Voltaire himself regarded physics as "an ill-bred tyrant" and looked with an unfriendly eye on works of popularization: "The delicate art of embellishing even philosophy with charms was still a new thing, of which the book of the worlds offered the first example, but a dangerous example because the real adornments of philosophy are order, clarity and above all truth." [1] Later he moderates his judgment: "It must moreover be observed that since the last century has taught the present, it has become so easy to write mediocre things that we have been inundated with superficial books, and what is much worse, with serious but useless books; but among this flood of mediocre writings—an evil which has become a necessary one in a huge, opulent and idle town where half the citizens spend their time amusing the other half—there are to be found from time to time excellent works,

1. *Le siècle de Louis XIV, Chapter XXII.*

either of history or of reflection, or of that light literature which serves as a relaxation for all sorts of minds." [1]

As for Rousseau, not only is science in his eyes the source of the degeneration of manners, but popularization is the worst of all evils. ". . . If the progress of the sciences has added nothing to our real happiness, if it has corrupted our manners and if the corruption of manners has poisoned the purity of taste, what shall we think of this throng of authors tempted to oversimplify who have dragged away from the temple of the Muses the difficulties which barred the entry to it and which nature had set there to test the strength of such as might be tempted to know? What shall we think of these compilers of works which have rudely broken in the door of the sciences and let into their sanctuary a mob unworthy of approaching it, whereas any sensible man would wish to see all those who could never advance far in the career of letters repelled at the outset and flung back on the arts useful to society?" [2] For many a man who will never in all his life be anything but a bad geometrician might perhaps have become a great "fabricator of materials", and the great masters, such as a Bacon, a Descartes and a Newton, did not need any other teachers than themselves.

Despite the voice of Rousseau, which was to find its echo in each succeeding generation, scientific knowledge extended ever more widely and more deeply. The final victory of the party of science may be said to have corresponded with the end of the war of the classics and the moderns, which started in 1687 and brought to a head the latent revolt of the partisans of progress against the blind worship of antiquity. All the big names of the age figured in it, and Fontenelle was naturally to be found among the moderns. In its literary form, the war came to an end in 1699 with the victory of the moderns. Their clinching argument was the indefinite progress of the sciences, which indisputably went far beyond anything attained by classical science. The incident, however, had repercussions far beyond the field of literature and the academies. It was the first episode of a struggle which was to widen in the following century when the war of the classics became identified with the cause of progress. This battle could break out of the domain of theory into that of action, for the principal arguments used were by that time known, not only to philosophers but also to politicians, men of action and an ever-growing public.

For it was not only the men of science who drew the conclusions from their new picture of the universe, but the men of letters, the philosophers, the Encyclopaedists. They formed a sort of link between science and action. When the value of antiquity was called in question, that of all established order, Church, Crown and Parliament was shaken. At the same time the idea

1. Ibid.
2. Rousseau, *Discours sur les sciences et les arts*, 1749.

began to spread, among the people who were neither philosophers nor scholars but men of action, that scientific methods should be capable of being applied to human problems. Already in the seventeenth century Vauban, in the course of his travels up and down France, had conceived the idea of collecting demographic and economic documents of all kinds, and had tried to deal with them scientifically; he had drawn remarkable conclusions from them as to the possibilities of expanding the country's trade. It was at this time too that there appeared the first works of statistics applied to economics and finance, that Sir William Petty, in his *Political Arithmetic,* showed the importance of statistics in the art of governing, and that the Abbé de Saint Pierre proposed the establishment of a sort of scientific council of politicians whose duty it would be to enquire into the improvement of economic affairs. About the same time, Fontenelle was writing, in the *Utilité des mathématiques,* that the geometrical approach could be applied to any branch of human knowledge.

Thus propagated, the new scientific spirit, with its elements of revolt against tradition and authority and of faith in the value of human reason, ended up, at the close of the century, with the French Revolution and the establishment of the Western democracies. Its endeavours to discover a point of contact with the working of human societies took longer to win recognition. They took form in the nineteenth century in the great social theories such as positivism or Marxism. But they have not yet found a fulcrum, and a strictly scientific human science still remains to be elaborated.

REPORTS AND DOCUMENTS

THE PARLIAMENTARY AND SCIENTIFIC COMMITTEE OF GREAT BRITAIN,

by M. Philips Price, M.P.

Mr. M. Philips Price, British author and journalist, Member of Parliament from 1929 to 1931 and again since 1935, was chairman of the Parliamentary and Scientific Committee from 1946 to 1952. His interest in science dates from his university days: educated at Harrow he graduated from Cambridge with honours in science. Correspondent for the Manchester Guardian in Russia *(1914-18) and the* Daily Herald *in Berlin (1919-23), he is the author of a dozen books on international affairs, particularly on Russia, Germany, and the United States, as well as on diplomatic history and economic problems.*

It is always difficult for people in one country to understand exactly how the parliament and constitution of other countries work in practice, and the British Parliament and the unwritten constitution of Great Britain present particular difficulties in this connexion.

One starts off with the fundamental difficulty that the committee system which prevails in the great majority of European and the American parliaments does not exist in the British Parliament at all. Whereas in the U.S.A. and in most European parliaments there are important functions attaching to such committees as the foreign affairs committee, finance committee and so forth, the British Parliament provides no such parallel.

There has always been a fundamental reluctance in Britain to allowing committees of Parliament to exercise power over the government of the day and over the executive. This power belongs, as it is conceived, to the full assembly of Parliament alone. It is of course, often necessary, owing to the pressure of business, to delegate some of the work of Parliament to committees. Bills are frequently sent to what are known as standing committees which are composed of members of all parties in the same proportion as in the whole House. But standing committees have to report back to the whole House, which may alter what the committee has done. On the other hand the budget is never sent to a special committee, nor are the Foreign Office estimates nor the estimates of the great supply services. These are always dealt with by the whole House, which resolves itself into a committee of the whole House for the purpose.

There are of course a number of official Parliamentary Committees, but these do not concern themselves with current legislation or control of the executive. There is, for instance, the Committee of Privileges, which meets whenever there is an issue of privilege of the House to be decided: there is the Public Accounts Committee, which reviews the accounts of selected government departments and reports thereon to Parliament; there is the Estimates Committee, which performs a similar function with regard to selected estimates of government departments, and so forth.

For the rest, committees in the British Parliament mainly consist of comparatively informal groups, either of members of one party or of all parties, concerning themselves with particular subjects. These are virtually study groups and merely help to provide a focus for discussing and forming views about particular issues.

For instance, both the Conservative and Labour Parties have such informal groups to deal with the major aspects of government, whether it be finance, agriculture, transport, etc. There are also a certain number of informal all-party groups, which have grown up spontaneously and have a varying degree of influence on the subjects with which they concern themselves. There is, for instance, an all-party group concerning itself with tourism and health resorts, and another dealing with animal welfare.

The Parliamentary and Scientific Committee is one of these informal all-party groups, but is has, for one reason or another, managed to establish itself with more continuity and formality. It is, however, very definitively an unofficial body and an all-party one, membership of which is open to members of any party in both the House of Lords and the House of Commons, and also to the nominated representatives of those scientific and technological organizations in the country which, under its constitution, can be affiliated. No organization can be a member of it which is engaged in promoting some scientific process or project for profit or commercial gain. Societies must be engaged in research or scientific education or be concerned with protecting or advancing the interests or professional well-being of those engaged in scientific work.

The Parliamentary and Scientific Committee receives no subvention whatsoever from the government or from any political party, and its modest revenue is drawn from the voluntary subscriptions of the peers and members of Parliament who belong to it and also from the subscriptions of the affiliated scientific bodies. Its approximate annual revenue from these sources does not broadly amount to more than £1,500 a year, a sum which is, of course, only sufficient to enable it to maintain a part-time staff and to organize a limited number of meetings, deputations, etc. and generally to stimulate a certain amount of useful activity in the Parliamentary field so far as scientific and technical issues are concerned.

The committee has sought to become a centre in the British Parliament for the consideration of any scientific or technological question which may possibly have a useful bearing on the current of future activities of Parliament or government. Those who founded the committee thought that very definite benefits might result if public-spirited representatives of the various societies concerning themselves with science and technology could meet together from time to time with a voluntary group of members of Parliament and peers who appreciated the important contribution which science can make to the government of any country in modern times, so that both Parliament and government departments should receive a continual stimulus and encouragement to take into account what science and technology can contribute to a wide range of public affairs.

One result of the enormous advance of science during recent decades has been that scientists and technologists tend to become more and more specialists in their own field and to use a language and form of expression peculiar to themselves, and less and less comprehensible not only to the layman but to the well-intentioned statesman, civil servant or member of

Parliament. Thus there is a very real need to find some means by which the representatives of the various branches of science and technology can be brought out of the ivory towers of research who are only too anxious to make use of the fruits of their knowledge and research, if it is made clear to them how that can be achieved in practice. In a modest way the Parliamentary and Scientific Committee in the British Parliament has made a practical attempt to achieve this fusion, and by bringing together this group of representatives of a wide range of sciences and technologies with a number of peers and members of Parliament who are well disposed towards the better use of science, it has been able in a number of ways so to influence the development of government policy as to enable the benefits of scientific research and technological advances to be applied to practical problems.

The aims and objects of the committee, as set out in its literature, are as follows:

1. To provide members of Parliament with authoritative scientific information from time to time in connexion with debates.
2. To bring to the notice of members of Parliament and government departments the results of scientific research and technical development which bear upon questions of current public interest.
3. To arrange for suitable action through parliamentary channels whenever necessary to ensure that proper regard is had for the scientific point of view.
4. To examine all legislation likely to affect the above and take such action as may be suitable.
5. To watch the financing of scientific research.
6. To provide its members and other approved subscribers with a regular summary of scientific matters dealt with in Parliament.

A good general description of the committee's work was given by Lord Samuel when he spoke as president of the committee at the annual luncheon on 11 February 1943. He said:

"Parliament, of course, has other functions to perform besides the duties of legislation, and of supervising the administration of the country; among other it is a liaison between public opinion and the government of the day, and nowhere has such a liaison been more needed than in the utilization of the scientific resources of the country. I do not know whether it is because most of our rulers have been educated classically, but few of them in the past were in any degree science-minded, and it was not long ago since few members of the government had any knowledge of any scientific authority more recent than Aristotle!

"The Parliamentary and Scientific Committee, formed in order to facilitate that liaison, does fulfil a need. It is not appointed by the Houses of Parliament, it is not nominated by any minister, it is wholly unofficial, self-appointed, self-financed; it consists of members of both Houses and of representatives of a number of associations, professions and industries utilizing applied science in various forms, and it is called the Parliamentary *and* Scientific Committee for the reason that it consists not only of members of Parliament but also of outside institutional authorities.

"The committee holds regular and frequent meetings; one of the largest committee rooms in the House of Commons is crowded by the members of Parliament, the peers and the representatives of the industries and professions who attend, and many practical methods are discussed with keen interest.

"Debates in both Houses have been instituted; deputations and conferences are organized and specific points presented mostly by these organizations are considered

by the committee, and if the case requires it, representations are made to the government either directly or through parliamentary action. Furthermore, we have the useful and salutary function of occasional criticism. A government team, however well intentioned, is rather like slow-going oxen and sometimes needs the goad."

In a more recent reference to the committee, on 11 June 1952, Viscount Samuel said:

"A group of members of the House of Commons conceived the idea of forming a new organization which would link together members of the two Houses and the working scientists. So was formed the Parliamentary and Scientific Committee, and that body now consists of 123 members of the other House, 36 members of your Lordships' House and the representatives of no fewer than 74 of the principal associations dealing with the professions and vocations relating to applied science. That committee serves a double link. On the one hand, it brings together the parliamentarians and the scientists and, on the other hand, it links both in combination with the ministers and the government departments. It has served a most useful purpose. The committee at present is unique in the parliaments of the world, but many countries are now inquiring into its working with a view possibly to following its example."

Professor E. D. Adrian (President of the Royal Society) said at the annual luncheon of the committee in 1950:

"You know much better than I how far your committee was able to contribute directly to the use of science in the war, but I can assure you that it made and still makes a very great indirect contribution by keeping up the morale of scientists. In times of stress it is very easy to become discouraged and critical of authority and red tape. . . . And as you know, the most brilliant scientists can be as unreasonable as the rest of us. But the knowledge that there is this powerful committee, not having to be loyal to particular parties or ministers or ideologies and interested only in seeing that scientific knowledge is not wasted, that was a great encouragement to us in the war and it remains so . . . at present."

Its main purpose was well described by Mr. Hugh Linstead, M.P., in the American magazine *Science* (July 1948):

Scientists do not make the best politicians nor do politicians make the best scientists. Yet science and politics interact one on the other and there is a real need for some common meeting place. In Great Britain the Parliamentary and Scientific Committee is the means we have found for bringing the two groups together so that the scientist can influence the development of political questions, the politician can advise the scientist on the practical aspects of some of his problems, and the two together, politician and scientist, can join in representations to the government.

Speaking at the committee's annual luncheon in 1943, Mr. Attlee, then Lord President of the Council, said that he had read and studied all the valuable reports which the committee had issued, particularly that on the universities. He regarded the committee as a very valuable partner in the work of making government, Parliament and people more scientifically minded. Its activities helped to create the right background for advance not only in government research institutions but in industry as well.

ORIGIN

The Parliamentary and Scientific Committee was formed at the end of 1939. Previously there had been in the British Parliament a small unofficial group of members of Parliament and representatives of some of the scientific organizations, known as the Parliamentary Science Committee.

This body, however, decided to dissolve itself at the outbreak of the war. Some of those who had been associated with this Parliamentary Science Committee protested against the proposed suspension and decided to set up a new organization to take its place.

A meeting for this purpose was summoned by Mr. S. F. Markham, M.P., the former chairman of the Parliamentary Science Committee, on 8 November 1939, when the following resolution was passed: "(a) That this meeting of ex-members of the Parliamentary Science Committee expresses its regret at the dissolution of the committee and (b) that it urges the desirability of the continuance of the activities of the PSC in some form throughout the period of hostilities and accordingly moves that an emergency committee be formed forthwith to represent the former PSC and to continue the work previously undertaken by that committee."

At a further meeting it became clear that there would be adequate support for the new body and it was formally set up as "The Parliamentary and Scientific Committee". By the early months of 1940 the committee had already obtained the support of 18 members of Parliament of various parties, and of some 20 scientific organizations, including: Association of Scientific Workers, Institute of Chemistry, National Veterinary Medical Association, Institution of Structural Engineers, British Association for the Advancement of Science, Institution of Mechanical Engineers, Institute of Gas Engineers, Institute of Petroleum, Society of Public Analysts and Other Analytical Chemists.

Since then the membership of the committee has increased considerably and according to the last annual report its membership comprised 161 peers and members of Parliament and the representatives of 74 scientific and technological organizations (see Appendix).

Its principal officers at present are:

President: Rt. Hon. Viscount Samuel, G.C.B., G.B.E.

Chairman: Sir Wavel Wakefield, M.P.

Vice-Chairman: Sir Henry Tizard, G.C.B., A.F.C., F.R.S.

Deputy-Chairman: Sir Ralph Glyn, Bt., M.P.; Mr. W. T. Wells, M.P.

Hon. Treasurer: Dr. H. J. T. Ellingham.

Hon. Secretaries: Mr. C. I. Orr-Ewing, C.B.E., M.I.E.E., M.P.; Mr. Austen Albu, B.Sc., A.M.I.Mech.E., M.P.; Dr. W. R. Wooldridge, M.Sc., M.R.C.V.S.

Active Vice-Presidents: Rt. Hon. Lord Haden-Guest; Rt. Hon. Earl of Halsbury; Mr. F. J. Erroll, M.P.; Mr. M. Philips Price, M.P.; Professor E. N. da C. Andrade, F.R.S.; Sir Ian Heilbron, F.R.S.

Honorary Members include: Professor A. V. Hill, C.H., F.R.S.; Sir Edward Salt; Professor Sir Robert Robinson, F.R.S.; Sir Edward Appleton, G.B.E., K.C.B., D.Sc., F.R.S.; Sir George Schuster, K.C.S.I., K.C.M.G., C.B.E.

A list of the affiliated scientific societies is shown in Appendix.

The rules setting out the qualifications of a scientific organization for membership are as follows:

"(i) An organization or society shall be eligible for election by the General Committee if the latter is satisfied that it is either: a national institution or association of qualified scientists or technologists, or a research organization, or a body, the special position of which in the scientific life of the country makes its membership, in the opinion of the General Committee, desirable in order to advance the agreed objects of the Parliamentary and Scientific Committee.

"(ii) Any organization or society, eligible for election to the committee (but not applying for such election) may, if it so desires, put forward a nominee for election as a 'nominated member' of the committee, provided that arrangements are made for such nominee to pay a subscription which is suitable, having general regard to the standing of the body by whom he is nominated and to the rules of the committee about subscriptions.

"(iii) Bodies claiming eligibility as research organizations shall be required to give evidence that either

(a) they are directly engaged in research in natural or social science, pure or applied, or

(b) they both provide funds for research to be conducted by other bodies and also take a direct part in determination of the programmes of such research."

Membership of the committee on the scientific side is limited broadly to national organizations of qualified scientists or technologists, to research associations, and a few bodies of special standing in the British scientific world, such as the British Association for the Advancement of Science.

As already indicated, the committee is purely an unofficial one and it was for this reason that the title "Parliamentary and Scientific Committee" was chosen in order to draw a distinction between this particular committee, and the formally appointed committees of either House of Parliament.

Writing to the chairman of the committee on 18 March 1943, the Clerk of the House of Commons, Sir Gilbert Campion (now Lord Campion) said:

"I am writing on Mr. Speaker's instructions in reply to your letter of 12 February, in which you consulted him on the propriety of using the title 'Parliamentary and Scientific' for the committee of which you are now chairman.

"Mr. Speaker has expressed his approval of the maintenance of the present title, subject to the adoption of the proposal put forward in your letter for adding the explanatory sub-title to the committee's stationery and publications.

"This course will secure continuity in your committee's record, which you would naturally not wish to be broken, and at the same time will distinguish it from the various committees appointed by the House of Commons."

HOW THE PARLIAMENTARY AND SCIENTIFIC COMMITTEE WORKS

Since the committee is an entirely unofficial body it must devise its own methods for bringing its influence to bear on parliamentary debates and government decisions.

Broadly speaking its activities can be separated under two main headings.

Firstly, it provides as far as it can for a regular exchange of information between members of Parliament and scientists; and secondly, it endeavours to ensure that something is done to right matters that are wrong in the light of such information.

So far as such action is concerned, it is obvious that an active all-party group of members of Parliament can achieve a great deal. It must be

remembered that the British Parliament has four main duties. It is one of the principal leaders of public opinion in the country; it controls the executive departments of government; it controls the country's finances, and it is the supreme organ so far as legislation is concerned.

Obviously it cannot carry out these duties effectively unless a reasonable proportion of its members is sufficiently well informed about the ever-increasing range of matters with which any parliament of today is obliged to concern itself.

Again, if members of Parliament are to be kept up to date with their information on the various subjects in which they are interested a great deal depends on organizations outside Parliament taking a continuous and intelligent interest in its proceedings. Unless this is done there is always a danger that members of Parliament will become isolated from current trends of opinion and from up-to-date information. Specialization is therefore essential, since it would be beyond the capacity of any one individual member of Parliament to follow effectively and in detail the widespread activities of Parliament as a whole.

It has, for instance, been estimated that at busy times when both the House of Commons and the House of Lords are sitting, and when at the same time several standing committees are meeting to deal with the committee stages of various bills, the output of parliamentary wordage may amount to well over one million a week and this of course is in addition to the vast amount of written parliamentary documents and papers.

When it is realized that in addition to this a member of Parliament has to deal with a considerable volume of correspondence not only from persons living in his own constituency but from any number of organizations and persons who feel that he ought to concern himself with their affairs as well, it is clear that it would require a superhuman individual to digest everything at his disposal in the parliamentary field.

The Parliamentary and Scientific Committee therefore endeavours to select and translate into terms which members of Parliament can understand some of the more important points arising from the vast amount of available and up-to-date information about scientific and technological matters, thus enabling them to take suitable action thereon in the parliamentary sphere if they so desire.

The following methods were adopted by the committee for this purpose:

Meetings are arranged in the House of Commons at least once a month when Parliament is in session, at which addresses are given by leading scientists or technologists on some particular subject of typical interest from the parliamentary or governmental point of view.

These addresses are usually followed by discussions and following the discussion a decision may be taken about consequential action in the parliamentary sphere.

This may take the form of questions asked by parliamentary members of the committee, the organization of a deputation to the minister principally concerned, or else the material may form useful data for some future debate in one or other of the Houses.

Addresses and discussions during the past three years:

21 March 1950. Dr. A. H. Bunting, M.Sc., D.Phil., Chief Scientific Officer, Overseas Food Corporation: Scientific aspects of the groundnut scheme.

4 April 1950. Commander Ian Cox, Science Director, Festival of Britain. (Also present: Mr. B. C. Sendall, Controller, and Brigadier J. L. P. Macnair): Scientific and technological aspects of the Festival of Britain.

2 May 1950. Sir Ben Lockspeiser, F.R.S., Secretary, Department of Scientific and Industrial Research: The work and future plans of the Department of Scientific and Industrial Research.

19 June 1950. Mr. R. McChlery, Central African Scientific Officer. Dr. J. G. Malloch, Scientific Liaison Officer to Canada. (Also present: Mr. J. E. Cummins (Australia); Dr. E. Marsden (New Zealand); Mr. J. P. de Wit (South Africa); Dr. V. S. Shembekar (India); Dr. (Miss) T. C. Marwick (U.K. Liaison Officer, B.C.S.O.): Scientific liaison between the Commonwealth countries.

25 July 1950. Sir Henry Tizard, G.C.B., A.F.C., F.R.S., Chairman, Government's Scientific Advisory Council: The work of the Advisory Council on scientific policy.

7 November 1950. Sir Geoffrey Heyworth, Chairman, Lever Brothers and Unilever Ltd. Mr. Lincoln Evans, C.B.E., General Secretary, Iron and Steel Trades Confederation. Sir Thomas Hutton, K.C.I.E., C.B., M.C., General Manager, Anglo-American Council on Productivity. Sir Charles Colston, C.B.E., M.C., D.C.M., Chairman and Managing Director, Hoover Ltd.: Productivity.

20 February: Sir John Cockcroft, C.B.E., F.R.S., Director, Atomic Energy Research Establishment, Harwell: The progress of atomic energy and development in Great Britain.

20 March 1951. The Rt. Hon. The Earl of Halsbury, Managing Director, National Research Development Corporation. (Also present: Mr. W. E. J. Johnson, Managing Director, Power Jets (Research and Development Ltd.): The work and future plans of the National Research Development Corporation.

1 May 1951. The Rt. Hon. Lord Hankey, Chairman, Colonial Products Research Council. Professor W. R. Jones, geological expert. Professor P. A. Buxton, Professor of Entomology. Sir Charles Darwin, scientific member, Colonial Development Corporation: The application of science and technology in the colonial territories.

29 May 1951. Professor S. Zuckerman, C.B., F.R.S., Chairman, Natural Resources (Technical) Committee. Mr. A. M. Baer, Consolidated Zinc Corporation Ltd. Mr. W. A. M. Edwards, Commercial Director, General Chemical Division, Imperial Chemical Industries: What science and technology can contribute to overcome shortages of essential raw materials.

26 June 1951. Dr. Percy Dunsheath, C.B.E., Chairman of Convocation of the University of London, Chairman of the London Regional Board for Higher Technological Education, Director of Henley's W. T. Telegraph Works and other electrical concerns. Dr. David S. Anderson, A.R.T.C., M.I.Mech.E., Director, Royal Technical College, Glasgow: The future development of higher technological education.

24 July 1951. Mr. W. H. Walter, Assistant Chief of U.S.A. Mission for Production and Supply. (Also present: Dr. Alexander King, Chief Scientific Officer, D.S.I.R., and Chairman, Scientific and Technical Committee of OEEC.): The assistance given by the ECA mission to the U.K. in the scientific and technological field.

20 November. Sir Nelson Johnson, K.C.B., D.Sc., Director, Meteorological Office: The organization, work and plans of the Meteorological Office.

4 December 1951. Dr. K. L. Blaxter, Hannah Dairy Research Institute. Dr. J. W. L. Beament, A.R.C., Unit of Insect Physiology, Cambridge (introduced by Lord Rothschild, Chairman, Agricultural Research Council): Agricultural research (with special reference to cows and insects).

18 March 1952. Dr. James Conant, President of Harvard University: Anglo-American scientific relations.

1 April 1952. Sir Godfrey Ince, G.C.B., K.B.E., Permanent Secretary to the Ministry of Labour. Sir George Schuster, K.C.S.I., K.C.M.G., C.B.E., honorary member of Parliamentary and Scientific Committee. Professor A. J. Lewis, M.D., F.R.C.P., Medical Research Council Unit for Research in Occupational Adaptation: Human relations in industry.

29 April 1952. Mr. T. M. Herbert, Executive Director of Research, British Railways: The present scope of the railway research programme.
20 May 1952. Dr. Ian Galloway, M.R.C.V.S., Director, Foot-and-Mouth Disease Research Institute. Dr. T. Bakker, Agricultural Attaché, Royal Netherlands Embassy. Mr. J. N. Ritchie, Chief Veterinary Officer, Ministry of Agriculture: Foot-and-mouth disease.
19 June 1952. Dr. A. W. Barton, Headmaster, City of London School. Professor W. E. Curtis, Professor of Physics, King's College, University of Durham, Newcastle-on-Tyne. Mr. G. N. Flemming, Deputy Secretary, Ministry of Education: The shortage of science teachers and its consequences.
22 July 1952. Debate on science and industry.

Again from time to time sub-committees have been set up to study and make recommendations about particular matters such as the increase of scientific manpower through the enlargement of the universities, the development of the technical colleges, and so forth.

Again through the year the committee publishes, particularly for the benefit of the outside scientific organizations affiliated to it, a document called "Science in Parliament", which contains a summary of all the main points concerning science and technology which have been dealt with in Parliament during the preceding weeks. This publication circulates widely amongst outside bodies, in addition to those affiliated to the committee, and quite a number of foreign governments subscribe to it.

An effort is also made by the committee's secretariat to keep those technological and scientific organizations which desire such a service, *au fait* with any information about points of particular concern to them in parliamentary debates and current legislation. This enables them to keep a watchful eye on all bills and debates in their own field and if necessary to supply information which will ensure that a decision is taken in the light of up-to-date technical information.

Reports are also issued by the committee from time to time and those of recent years include the following:

1943. "Coal Utilization Research in Great Britain."
"Scientific Research and the Universities in Post-War Britain."
1944. "A Scientific Policy for British Agriculture."
"District Heating."
1946. "Universities and the Increase of Scientific Manpower."
1947. "Colleges of Technology and Technological Manpower."
1950. "Technical Education and Skilled Manpower."
"Productivity."

It is obvious, however, that in view of the limited financial resources of the committee it is not equipped to prepare lengthy and complex reports and certainly could not do so very frequently. The committee regards its function far more as that of a high level and responsible kind of "pressure group", which notes any important reports or conclusions which may be issued about scientific matters and takes steps to persuade Parliament or the government of the day to initiate effective action thereon.

Lastly, the committee has for several years past made a practice of arranging visits, particularly for its parliamentary members, to research establishments of all kinds, so as to maintain a lively interest in what the research workers of the country are doing. This is welcomed by the research

establishment concerned, which appreciate an interest being taken in their activities and in a limited way it helps to ensure that good use is made of the fruits of their researches.

Visits have been arranged during the past two years to the following establishments:

25/5/50. Building Research Station, Watford.
15/6/50. Rothamsted Experimental Station, Harpenden.
28/6/50. Kodak's Research Laboratories, Wealdstone.
11/7/50. Road Research Laboratory, Langley.
25/7/50. Powell Duffryn Research Laboratories, Battersea.
8/2/51. BBC Television Studios and Units, Shepherds Bush and Wembley.
9/5/51. Fuel Research Station, East Greenwich.
14/6/51. National Physical Laboratory, Teddington.
19/6/51. East Malling Research Station.
29/6/51. National Coal Board Research Establishment, Stoke Orchard.
3/7/51. Lever Brothers Research Station, Bedford.
11/7/51. National Institute for Medical Research, Mill Hill.
24/7/51. Telekinema, South Bank Exhibition.
15/5/52. Central Forecasting Office of the Meteorological Department of the Air Ministry, Dunstable.
27/5/52. De Haviland Aircraft Company, Hatfield.
17/6/52. Anglo-Iranian Oil Company Refinery, Isle of Grain.
27/6/52. Atomic Energy Research Station, Harwell.
22/7/52. Ministry of Agriculture Veterinary Laboratory, Weybridge.

To sum up, it is unquestionable that this overall exchange of information between parliamentarians and scientists has a useful result. It not only stimulates members of Parliament, and indirectly government departments, to consider how science and technology can provide an effective answer to their current problems, but it also encourages many scientists and technologists to ensure that the fruits of their work are properly appreciated by the authorities.

It is of course for the parliamentary members of the committee, whether in the House of Lords or in the House of Commons, to take whatever action they think fit in the light of the information which comes to their knowledge at meetings of the committee and at visits to research stations and other informal contacts arranged by it.

Sometimes this action may take the form of tabling questions to the appropriate ministers. On other occasions the committee as a whole may take a formal deputation to argue the point out with the responsible minister. As a matter of general routine the parliamentary members of the committee endeavour to arrange for debates at fairly regular intervals in the House of Lords and the House of Commons on some general or particular aspect of science in relation to the problems of today.

The effectiveness of any action taken by the committee is of course directly related to the merits of the case which it puts forward and the reputation it can create for its impartiality and authority. Parliament and government departments are inevitably subjected to pressure from all sorts of interests about all sorts of matters but the Parliamentary and Scientific Committee has endeavoured to ensure that its influence is only used when a case has unquestionable merits.

Although a wide range of particular interests may be indirectly repre-

sented on it through the various scientific and technological organizations, no one of them can in consequence use the committee to put forward any pet idea of its own. It has always been a principle of the committee that it will only support a case or bring its influence to bear where it seems that an issue of national importance is involved. By adhering to this principle it has built up a position of authority and influence which it could not otherwise enjoy as an unofficial organization.

PARLIAMENTARY DEBATES ON SCIENCE

Towards the end of 1943 the Parliamentary members of the committee placed a motion on the Order Paper of the House of Commons, supported by the names of 207 members of all parties. This formed the subject of a full dress debate on 19 April 1944, when Sir Granville Gibson, M.P. proposed it in the following abbreviated form:

> To call attention to research and scientific knowledge; and to move, That this House, recognizing the vital part which research and science and their effective application can play in reconstruction, as a means of increasing our national prosperity, raising the standard of living, recovering our export trade and developing the national resources of our Empire, urges the declaration of a bold and generous government policy directed to the expansion of teaching and research facilities in our universities and technical colleges, to the extension of pure and applied research in all fields by the State, by industry through private firms and research associations, and to the effective and rapid application of the results of research.

In that debate no less than 17 members of the committee took part and as a result some important announcements of government policy were made by the Lord President of the Council (then Mr. Attlee), who replied on behalf of the government.

He stated that the government was in full sympathy with the terms of the Motion and gave an undertaking that government assistance would be given "on bold lines". He added that the government recognized that there must be a much greater expenditure on fundamental research and teaching and their needs in this respect would definitely be met. (The amount of government money made available to the University Grants Committee, which at the date was £2,250,000 per annum, has now risen to £23,500,000.

Mr. Attlee also stated that the government would ensure that there was an adequate supply of, and proper rewards to, scientific research workers and teachers and that the remuneration for scientists in government employment was under consideration. (An increased scale of payments was subsequently announced.)

Another general debate on science took place in the House of Commons on 5 May 1950, on a motion tabled by Mr. M. P. Price, M.P., then chairman of the committee, in the following terms:

> That in the opinion of this House, there should be the fullest development and utilization of Britain's exceptional scientific resources and manpower, with a view to ensuring effective progress in the development of our industry, agriculture and colonies, and a material improvement of our economic position in the world.

Thirteen members of the Parliamentary and Scientific Committee participated in the debate. The government reply was given by the Lord President of the Council (then Mr. Herbert Morrison) who, in his concluding words said:

> We can claim that the government fully recognize the importance and the complexities of the problem of putting Britain scientifically in the lead as a producer, as a supplier, and as a user of scientific ideas and discoveries. . . . I hope this debate today will have a beneficial effect upon the whole scientific world, so that scientists will realize that the House of Commons is interested in their work and wishes them well.

Another typical debate, which took place in the House of Lords on 11 and 12 June 1952, is referred to in greater detail later.

SPECIFIC EXAMPLES OF ACTIVITY BY THE PARLIAMENTARY AND SCIENTIFIC COMMITTEE

It is difficult to select particular examples of "campaigns" run by the Parliamentary and Scientific Committee during the 12 years in which it has been in existence, but the following are selected as giving a fairly comprehensive picture of how things work out in practice, both during the war and in the post-war period.

The Proper Utilization of Scientists in the War

This was a matter of constant concern to the Parliamentary and Scientific Committee during the period 1941-43 and quite early in the war members had serious misgivings about the failure to make proper or co-ordinated use of the scientific and technological resources of the country.

The matter was first raised by Viscount Samuel, a very active member of the committee, in the House of Lords on 2 April 1941, when he rose to ask the government "whether they can make any statement on the extent to which the assistance of scientists has been enlisted in the prosecution of the war; and to move for papers".

He urged that greater use should be made of industrial men of science such as chemists and physicists engaged in industry, or in practice as consultants. He referred to the criticism that scientists in government departments were not sufficiently in touch with operations, and asked what steps were being taken to secure co-operation between American and British science in the prosecution of the war.

There was also considerable correspondence during 1941 between the chairman of the committee and the Lord President of the Council on this subject, and a sub-committee was set up to draft detailed recommendations. Gradually things began to improve, and at the committee's annual luncheon on 3 February 1942, the distinguished scientist, Sir Henry Tizard, was able to say that:

> The influence of science is now greater than it has ever been, and the present government and Parliament attach a value to the help and guidance of scientists that no previous Parliaments have ever done. Lord Hankey has already told you something of the work of the scientific committees over which he presides. There are many more such committees that I could mention. There is hardly a phase of the national life now

with which scientists are not associated. In fact a fighting friend of mine said that he could hardly walk in any direction in this war without tumbling over a scientist who had got in the way. . . .

And then, what previous Prime Minister of England ever had a scientific adviser continually at his elbow? He is not the only minister who has a scientific adviser. Even commanders-in-chief have them, as General Pile, who is here, would blushingly admit.

Sir Henry Tizard pointed out that although there was this large amount of scientific talent available to the government, he doubted whether the right use was being made of it in all cases. He said:

So far as the strategy of science is concerned, I am not so confident. Much has been done to improve it, but much remains to be done. The strategy of science is again similar to that of war. The strategy of pure science is to attack at the weakest spot of the barrier to knowledge. The secret of science is to ask the right question, and it is the choice of the problem more than anything else that marks the man of genius in the scientific world. The strategy of science applied to war is to attack at the point where the dividends are greatest in relation to the effort. Our tactical strength is great, but it is not unlimited. We cannot afford to dissipate our efforts over things that do not matter or do not matter much, and we must remember, too, that any technical advance, to have a decisive effect in war, makes big demands on the productive capacity of the country.

He accordingly urged the Parliamentary and Scientific Committee to concentrate on ensuring more effective co-operation between all branches of the government and its scientific advisers.

After the sub-committee had evolved detailed recommendations on the issue, a deputation was appointed to wait on Mr. R. A. Butler, M.P., who had recently been appointed chairman of the government Scientific Advisory Council, and whom it saw on 16 July 1942. The main point urged by it was the setting up of a more effective scientific organization to inspire the scientific and technical direction of the war. Mr. Butler undertook to pass on the views expressed to the Lord President of the Council and the Minister of Production.

Further action was taken by the parliamentary members of the committee, by the placing of a motion on the Order Paper of the House of Commons on 28 July 1942, stating that the effective prosecution of the war required the early establishment of a central organization to co-ordinate research and developments in relation to the war effort and to ensure that the experience, knowledge and creative genius of British technicians and scientists exert a more effective influence over the conduct of a highly mechanized war. That motion received the support of 145 members of Parliament of all parties.

The main outcome of all these representations was undoubtedly to cause a considerable improvement in the government's arrangements for the scientific direction of the war and one of the most important of these was the decision to appoint three leading scientists as scientific advisers to the Minister of Production.

With regard to the appointment of these advisers the Parliamentary and Scientific Committee unanimously passed the following resolution at its meeting on 8 September 1942:

This committee, while welcoming the appointment of three full-time scientific advisers

to the staff of the Ministry of Production in so far as it establishes the nucleus of a central scientific and technical board, regrets that their field of activity is apparently to be limited to the sphere of production and does not include the scientific and technical activities of the service departments or the other ministries outside the strict field of production. An extension of its functions is needed to ensure that all scientific considerations are co-ordinated and given full weight over the whole field of the national effort. The committee considers, therefore, that in order to cover this wider field, scientific advisers should have direct access to the War Cabinet and that accordingly the Lord Privy Seal should exercise his supervisory functions over the new body directly on behalf of the War Cabinet.

This was sent to the appropriate ministers and the press, and Sir Stafford Cripps, Lord Privy Seal, replied as follows:

I think that it would be wise at the present time not to press for any more precise definition of the functions of the scientific advisers who have been appointed, but rather to let me handle the position as best I can with a view to their gradual establishment and the extension of the scope and value of their work. Very often if one tries to make the directives on this sort of question precise, one only ends by limiting rather than extending the powers.

Sir John Anderson (now Viscount Waverley), Lord President of the Council, referring to this question at the annual luncheon of the committee on 11 February 1943, said:

I am, and have been for a long time, fully conscious of the feeling which has existed that there was something not quite right in the higher organization of our scientific effort in relation to the functions of government, and it has been my business as minister specially concerned within a limited field with scientific matters to study this particular problem and see whether means could be found of improving the organization.

Income Tax and Research Expenditure

A sub-committee was set up by the committee on 7 December 1943. A report from this body recommending that all expenditure on research should be regarded as expense chargeable against profits for income tax purposes and making a number of other suggestions, was sent to the Chancellor of the Exchequer in January 1944, and a further discussion about these recommendations took place between the chairman of the sub-committee, Sir George Schuster, and Sir Cornelius Gregg, chairman of the Board of Inland Revenue.

To the great satisfaction of the committee Sir John Anderson's budget of 1944 contained proposals on the lines suggested by the committee. He said:

My proposal is that any research expenditure of a capital character, which means normally expenditure on laboratory buildings, plant and machinery, should be allowed over a period of five years, or over the life of the assets if shorter, as a deduction from profits for income tax purposes. In addition, all current research expenditure such as salaries, wages, cost of materials, repairs, and so forth, will be allowed as and when incurred by the trader. . . .

In addition I propose that any payment, whether for a capital purpose or not, made by a trader to a central research body approved by the Department of Scientific and

Industrial Research, shall be allowed, as and when made, as a deduction in computing the profits of the concern. Contributions to research being carried out by a university or college on matters of concern to the trader's business will be similarly allowed. . . .

At a meeting on 9 May 1944, the following resolution was unanimously passed and transmitted to the Chancellor:

That this committee welcomes the valuable reforms with regard to the taxation of research announced by the Chancellor of the Exchequer in his recent budget statement. It regards the changes which it is proposed to make as providing a real opportunity for British industry to embark on a programme of research and development on a far greater scale than hitherto, with advantage not only to itself but the national interest as a whole. In expressing their gratitude to Sir John Anderson the committee expresses the confident hope that he will go down in history as the Chancellor responsible for the re-development of British industry on truly scientific lines.

Scientific Manpower

Scientific manpower, whether in the form of science graduates produced in the universities, technologists produced in the colleges of technology, or technicians produced from various sources, has been a question which has engaged the attention of the committee for several years, down to and including 1952. This question has been the subject of three specific reports prepared by sub-committees and endorsed by the committee as a whole, namely the following:

1946. "Universities and the Increase of Scientific Manpower."
1947. "Colleges of Technology and Technological Manpower."
1950. "Technical Education and Skilled Manpower."

During 1952 this issue has been dealt with by the committee in the following way:

In the first place, Lord Woolton, Lord President of the Council, was invited to address the committee at a meeting on 27 February. He said:

The need to make the fullest industrial use of scientific and industrial research leads on to the question of technical and technological education. It is strange that there should be so much controversy on the subject because the facts are after all so simple. Higher production and higher productivity come from increasing technological knowledge and skill and these in turn come from employing more and more highly trained technologists and technicians. There is no question at all that our balance of payments problems and our defence problems at this moment are basically production problems and that our production problems are primarily problems of technology. Here again, if industry would open its mouth wider and ask more loudly and more urgently for more technologists and technicians many remaining doubts and disagreements would be removed and the problem of educating the right people in the right ways would fall into perspective.

Let me quote one or two figures. In America in 1949 the total number of degrees awarded in science and technology was about 110,000. In Great Britain in the same year the number of corresponding degrees, including higher national certificates and higher national diplomas, was only about 14,000. Even after adjusting for the difference in the size of the labour force in the two countries, American industry engages every year now three scientifically-trained men for every one that British industry engages. The American Institute of Management reports that 75 per cent of the

presidents of 204 leading industrial companies are graduates, mainly scientists. I wonder what the comparative figure would be here. I suspect it would be a great deal lower and it has been reduced by one since I joined His Majesty's Government last autumn. However, let us give credit where credit is due and I am very glad to notice the very marked trend in this direction among some of our leading firms. Imperial Chemical Industries, for example, have, in the past 18 months, promoted to be managing directors of divisions no less than seven heads of research departments. Progressive small firms as well as large are increasingly adopting this line.

Later in the year Viscount Samuel, the committee's president organized a debate in the House of Lords on 11 and 12 June during which the question of scientific manpower and the shortage of technologists was one of the main questions raised.

Prior to this debate the Parliamentary and Scientific Committee issued a questionnaire to the scientific organizations affiliated to it, in order to obtain up-to-date material for use by peers participating in the debate. The questions which were put were as follows:

1. To what extent is effective use made by the industry or industries with which you are concerned of the results of scientific research and what, if any, are the present obstacles to the better or more rapid utilization thereof?
2. To what extent are the industry or industries with which you are concerned short at the present time of technical, technological or scientific staff, and are any particular difficulties expected in the future?
3. Have you any views about better arrangements for the higher education of technologists employed in the industry or industries with which you are concerned?
4. Have you any other suggestions as to what further useful action could be taken by the government with regard to the financing of scientific research in this country, or with a view to ensuring the better utilization of the results of such research by industry, agriculture, etc.?

Seventeen out of the 24 peers who participated in the debate were members of the Parliamentary and Scientific Committee, and amongst the questions which they raised the issue of scientific manpower was prominent.

Replying for the government, Lord Woolton made an important formal statement of government policy on this subject, as follows:

> The government consider that a most important means of increasing productivity in industry is to improve facilities for higher technological education. They are convinced that this can best be done by building up at least one institution of university rank devoted predominantly to the teaching and study of the various forms of technology. We are, therefore, urgently exploring the practical possibilities as to the best way of doing this. As regards the last government's White Paper. . . . I should say that we fully recognize the important contribution which technical colleges can make to higher technological education, and details of our proposals for improving financial assistance available for selected colleges and courses will be shortly announced by the Ministry of Education. We do not, however, propose to establish a non-teaching, award-making body under the title of the Royal College of Technology.

Enlarging on this point Lord Woolton added that despite the cautious words "urgently explore" the government had every intention of doing something practical about this matter.

The debate itself was subsequently analysed and further discussed at a general meeting of the Parliamentary and Scientific Committee. A deputation was then appointed to wait upon the Lord President of the Council on

28 July 1952, with a view to discussing further with him various important issues which had arisen during the debate, including that of scientific manpower.

In the memorandum submitted to the Lord President, one of the principal parts dealt with scientific manpower in the following terms:

> Referring to the shortage of technologists, Lord Woolton, when intervening in the House of Lords debate on science on 11 June announced that the government had decided, first to build up one institution of university rank devoted predominantly to the teaching and study of the various forms of technology, and secondly that there would be proposals for improving the financial assistance available for selected technical colleges and courses.
>
> The Parliamentary and Scientific Committee would like to have some further information as to the steps which are now to be taken with regard to these two proposals, since it is of the opinion that the shortage of technologists is one of the major difficulties standing in the way of the more effective application of science to industry in this country.
>
> The committee agrees with the Report of the Advisory Council on Scientific Policy (paras. 8 and 27) on the importance of increasing the number of scientifically-trained men appointed to senior managerial and executive posts. In order to give a lead to this policy it would ask the government to consider the present situation in the Scientific Civil Service and in the Defence Ministries, with a view to ensuring that those appointed to the scientific grades have at least as good prospects of pay and promotion to the highest positions as those in the administrative grades.
>
> The committee strongly endorses the main conclusions contained in the last report of the Advisory Council on Scientific Policy dealing with this matter, as follows:
>
> *Cmd. 8561, Para. 35*
>
> (ii) There is a pressing need to increase both absolutely and relatively the number of scientists in our industries.
> (iv) There is likely to be a long-term shortage of practically all kinds of scientists; every effort should be made to increase the supply, with particular emphasis on chemists, chemical engineers, electrical engineers, mechanical engineers and physicists.
> (viii) Further consideration should be given to the fact that there is a shortage of science graduates.
> (ix) The output of scientists from technical colleges can be increased relatively quickly, provided employers encourage the flow of students.
> (xvii) The inadequate supply of good science teachers is giving serious concern.

It is not possible at this stage to disclose Lord Woolton's reply, since he asked for it to be treated as confidential, but the members of the deputation came away convinced that in this particular field the government does mean business and has taken note of the recommendations made by the committee.

Coal Utilization and Fuel Economy

One of the earlier reports put out by the committee during the war, in 1943, and one which attracted more attention than any other at the time, was its first report dealing with coal utilization research. In it great stress was laid on Great Britain's dependence on coal as its only main raw material and various ways were suggested in which coal utilization research

might be further developed. The report created nation-wide interest and started a campaign which has developed into one for the maximum economy in the use of our fuel resources.

This campaign was given some prominence in a debate initiated in the House of Commons by the author of this article on 7 March 1952. The motion which he proposed and which was accepted by the House called for vigorous measures by the government and by industry to discover and to apply in practice the best possible methods for conserving fuel resources and for their utilization in the most efficient manner.

In the debate several members of the Parliamentary and Scientific Committee took part and the facts brought forward were for the most part facts which had been collected by the committee and had been incorporated in its reports. Thus it was suggested that economy in the use of coal could reach the figure of 20 million tons a year, if certain measures were taken. This would make it possible for Great Britain to raise her export of coal to Europe and improve her balance of payments. It was shown to be necessary to increase the use of stoves and closed heating appliances in houses, which would raise the efficiency of the fuel used from 20 per cent to 50 per cent. In industry, the use of better insulation, modern methods of stoking and the installation on new types of boilers was recommended.

As a result of this debate the Minister of Fuel and Power, Mr. Geoffrey Lloyd, announced that the government were prepared to offer the sum of £1 million as loans to industry to enable it to install fuel-saving apparatus of approved kinds.

This is then the most recent example of the kind of influence which the Parliamentary and Scientific Committee has in Parliament and on the government, and the kind of work it does where broad national and international interests are the chief consideration.

APPENDIX

Scientific and Technical Organizations affiliated to the Parliamentary and Scientific Committee

Association of Applied Biologists
Association of Scientific Workers
Association of Technical Institutions
Biochemical Society
British Association for the Advancement of Science
British Association of Chemists
British Cast Iron Research Association
British Ceramic Research Association
British Coal Utilization Research Association
British Cotton Industry Research Association
British Council (Science Department)
British Electrical and Allied Industries, Research Association
British Institution of Radio Engineers
British Iron and Steel Research Association
British Launderers' Research Association
British Leather Manufacturers' Research Association
British Non-Ferrous Metals Research Association

British Optical Association
British Rayon Research Association
British Rubber Producers' Research Association
British Scientific Instrument Research Association
British Shipbuilding Research Association
British Veterinary Association
British Welding Research
Chemical Society
City and Guilds of London Institute
Coke Oven Managers' Association
Combustion Engineering Society
Faraday Society
Illuminating Engineering Society
Institute of Fuel
Institute of Marine Engineers
Institute of Metals
Institute of Petroleum
Institute of Physics
Institute of Welding
Institution of Chemical Engineers
Institution of Heating and Ventilating Engineers
Institution of Metallurgists
Institution of Mining and Metallurgy
Institution of Mining Engineers
Institution of Municipal Engineers
Institution of Professional Civil Servants
Institution of the Rubber Industry
Institution of Structural Engineers
Iron and Steel Institute
Linen Industrial Research Association
Motion Study Society of Great Britain
National Association of Colliery Managers
National Farmers' Union (Development and Education Committee)
National Institute of Economic and Social Research
National Smoke Abatement Society
Nutrition Society
Oil and Colour Chemists' Association
Pharmaceutical Society of Great Britain
Physical Society
Physiological Society
Printing and Allied Trades Research Association
Research Association of British Paint, Colour and Varnish Manufacturers
Research Association of British Rubber Manufacturers
Research Defence Society
Royal College of Veterinary Surgeons
Royal Institute of British Architects
Scientific Film Association
Society of Chemical Industry
Society of Dyers and Colourists
Society of Public Analysts and Other Analytical Chemists
Textile Institute
Tin Research Institute
Universities Federation for Animal Welfare
Wool Industries Research Association

BOOKS AND PUBLICATIONS

ANGLO-AMERICAN RELATIONS IN THE ATOMIC AGE,
by James B. Conant, Oxford University Press, London, 1952, 42 pp., 5s.

The third Stevenson Memorial Lecture, delivered on 17 March 1952, at the London School of Economics by the President of Harvard University, deals with a subject which is an excellent illustration of the impact of science on society—in this particular case, on the special aspects of Anglo-American relations that are a product of the atomic age.

The main point of President Conant's address is that, while the application of science to war is no new phenomenon, the advent of the atomic bomb did introduce a novel and highly significant element into the relationship between science and war. This was due partly no doubt to the revolutionary military potentialities of the new weapon; but the fact of prime importance is that, in the period 1940 to 1945, a very large number of Anglo-American specialists was engaged both in advancing science in a spectacular fashion and in manufacturing a new weapon of great military power. This was a new social phenomenon; and we are still struggling with its consequences.

In all cases of application of science to war until 1945, the technical area of the new knowledge was small and easily circumscribed. Such was the case of poison gas in the first world war—even had this new weapon been far more effective than it proved in reality. Only if in the process of discovering a new gas had the chemists unlocked a safe full of new chemical facts of great scientific significance, would this military application of science have caused an appreciable reorientation of scientific attitudes or of the attitude of society towards science. One can imagine, for example, that the work on gas warfare might have resulted in a whole new set of discoveries leading both to the ideal gas weapon and to a revolution in our ideas about the synthesis and metabolism of proteins opening up, for instance, an entirely new road to the possible cure of cancer. Under such imaginery conditions what would the security regulations in a divided world have demanded of the physiologists and the chemists?

A situation of this type has arisen for the first time in the field of nuclear physics. Science, technology, and politics have merged, and we have to face this highly unpleasant revolution in science and international relations. It is one of the facts of life in 1952—as is the armament race in atomic weapons—and there is no use wringing our hands about it, nor attempting to find scapegoats to blame for it.

It is important, however, to distinguish between the special position of nuclear science and the other fields of physics and chemistry. In the latter, the status of scientists working on weapons other than atomic is no different from that of their predecessors who manufactured the first smokeless powder or developed mustard gas. Their activities for military ends can be walled off from the rest of science, and thus the free and international character of

almost all of this vast area of physics, chemistry, and biology can be preserved. But nuclear physics has necessarily been pervaded by secrecy—and it is this secrecy which has created trouble, misunderstanding and bad feeling between Great Britain and the United States. President Conant thought in 1943, and still thinks, that a treaty dealing with everything even distantly related to atomic energy should have been drawn up between Britain, the U.S.A. and Canada. He regrets the existence of barriers to full Anglo-American co-operation in all aspects of applied nuclear physics—but he also thinks that the events of the last few years have made the removal of these barriers difficult, to say the least.

There is far too much malicious whispering on both sides of the Atlantic about the alleged carelessness of the British in keeping secrets and the alleged hysteria of the Americans about atomic spying. Yet, as President Conant points out, there have been far fewer serious consequences of this alleged hysteria in the U.S.A. than in several other periods of American history, particularly during the first world war and in the years that followed "the red scare" in 1918-19. President Conant has evidently a high regard for British traditions, both academic and national, and thinks that the British could greatly help by their example and by their counsel, but only if they will try to understand conditions in the United States and counsel rather than scold. The same remark, he thinks, applies to the criticism that comes from the U.S.A. The process of adjustment requires a careful weighing of the balance between the demands of security and the demands of liberty. But such an adjustment is surely not beyond the resources of the two nations.

"SOCIAL IMPLICATIONS OF TECHNICAL CHANGE",
International Social Science Bulletin, vol. IV, no. 2, pp. 243-346, Unesco, Paris, Summer 1952.

The summer issue of Unesco's *Social Science Bulletin* is devoted to the study of the social implications of technical change. In the introduction (pp. 243-60) Professor Georges Friedmann, of the Conservatoire national des arts et métiers and the Institut d'études politiques de l'Université de Paris, points out that it was only recently that the study of technical advances, and of their consequences for man and society, for institutions and ways of living, was given its appropriate place in the forefront of sociology as a whole. The scope of such an enquiry is tremendous, for it implies the study of almost every aspect of the changes which have occurred in contemporary society. The presentation of an overall picture of the social consequences of technical progress almost amounts to describing our industrial societies as a whole. The growth of technology has placed modern man in a totally different environment from that of a century and a half ago and has brought about so great a number of changes that one may legitimately speak of a new quality of civilization—the technological civilization. We have reached a stage at which it is no longer enough merely to accept and describe technical evolution. Its social consequences are both so tremendous and so threatening that its evolution must be foreseen and directed into appropriate channels. That, in Professor Friedmann's opinion, is the great task of the human sciences.

After this introduction, Professor S. Herbert Frankel, of Oxford University, tackles the problem by way of "Some conceptual aspects of technical change" (pp. 263-69). He draws attention to the tendency to speak of "the social consequences of technical change", and not of "technical change as a social consequence", i.e. the tendency to conclude that technical change is a kind of abstract force which has certain social consequences, and failure to see that what we describe as the consequences of this force are simply part and parcel of the activity itself. Numerous examples are adduced to illustrate this.

As Professor William Fielding Ogburn, of the University of Chicago, shows in his study of the "Social effects of technology in industrialized societies" (pp. 269-79), technology in fact acts in a variety of different ways (diversification, sequences and convergence), so that there is no longer any simple causality, but a pattern of causes, following tortuous lines, intersecting, branching, converging. Thus it would be very difficult to hold one change rather than another responsible for the development of institutions. It would even be inaccurate to consider such social changes merely as the consequences of technical processes, since the latter are themselves methods of production evolved by men and are therefore connected with certain types of human relationships. Nevertheless Professor Ogburn considers that the whole process lends itself to scientific analysis and anticipation. He recommends that there should be an annual census of inventions and discoveries combined with some attempt to forecast inventions, especially important inventions such as television. The various uses of inventions and scientific discoveries should be explored, and the time required for an invention to be used extensively enough to produce an impact on society should be estimated, at least in respect of important inventions. Finally, there should be attempts to foresee the social effects of important inventions, and investigations aimed at a more speedy removal of lags in the adjustment to important inventions which will have far-reaching effects. But all these objectives call for greatly expanded research in social science, the need for which is not widely enough recognized.

Another aspect of the problem, the "Social consequences of technical change from the sociological standpoint" (pp. 280-88) is treated by Professor Wilbert E. Moore, of Princeton University, who emphasizes the artificiality and inadequacy of the current theory of human relations, and stresses the need for taking into account from the beginning the human aspect of work, which is a phenomenon in its own right.

The economic aspect of the problem is the subject of a study by Professor Jean Fourastié, of the Conservatoire national des arts et métiers and the Ecole pratique des hautes études, Paris, under the title "Economics and the social consequences of technical progress" (pp. 289-300). He considers that we are witnessing the birth of a new branch of economic science, the object of which is to study the long-term effects of technical progress on economic evolution. He adduces a number of examples to show that technical progress has an influence on every single phenomenon of economic life, and particularly on the most important of all—the standard of living. Thus the idea of technical progress becomes the centre of economic science.

Mr. Einar Thorsrud studies "The social consequences of technical change from the psychological standpoint" (pp. 300-9) and assumes that it is from a psychological point of view, through their influence on human

motivation, that technological changes have such great social consequences. M. René Savatier, Dean of the Faculty of Law at Poitiers University, deals with "Law and the progress of techniques" (pp. 309-19), analysing the effect of law on techniques and the effect of techniques on law. Professor A. P. Elkin, of the University of Sydney, takes a concrete example from Australia and analyses the impact of Western technology on the Australian aborigines (pp. 320-28). Finally, Professor Harold D. Lasswell, of Yale University, in "Appraising the effects of technology" (pp. 328-39) sets out the conclusions to be drawn from these studies.

A "Tentative bibliography" (pp. 339-46) forms a useful appendage to this symposium.

"MACHINES AND MAN",
by Wassily Leontief, *Scientific American*, vol. 187, no. 3, pp. 150-60, September 1952.

The author, who is professor of economics at Harvard University, reviews in this study the economic and social impact of automatic control systems. The best index of the development of automatization in the United States is the annual production of measuring and controlling instruments, which is rising far more rapidly than the curve of plant investment as a whole. In many sectors, machines have by now practically eliminated the need for human muscle power. Man has all but ceased to be a lifter and mover and has become primarily a starter and stopper, a setter and assembler and repairer. Self-controlled machinery will further narrow the direct participation of human muscle power in the process of production. The starter and stopper will disappear first, the setter and assembler will go next; but the need for repairmen will increase.

All this will inevitably change the character of the labour force. We shall probably see an accelerated rise in the proportion of skilled workers, clerks and professional personnel. Such change may bring about considerable strain in a rigid and differentiated social structure. But in the U.S.A. the uniformity of American living renders the effects of such transition almost imperceptible; a family of a typical $3,000-a-year clerk spends its money in very much the same way as the family of a machine-press operator with a similar income. Nor is it necessarily true that automatization will create unemployment. For the amount of capital needed for each unit of output will be reduced further by the installation of automatic machinery, and labour should therefore be able to maintain or improve its relative share of the national income.

But increase in productivity leads to a reduction of working hours. The average work-week in the U.S.A. has been shortened from 67.2 hours in 1870 to 42.5 hours in 1950, a reduction which reflects a deliberate decision by the American people to enjoy an ever-increasing part of their rising standard of living in the form of leisure. In the future, the increased productivity due to automatization will be enjoyed even more.

But the new technology will probably have a much more revolutionary effect on the so-called underdeveloped countries than on the old industrial nations. Shortage of capital and lack of a properly conditioned and educated labour force have been the two major obstacles to rapid industrialization of

economically backward areas. Automatic production, with its relatively low capital and labour requirements per unit of output, radically changes the prospects of these areas. Instead of trying to lift the whole economy by the slow, painful methods of the past, they may take the shortcut of building a few large, up-to-date automatic plants. The oil refineries of the Middle East, the integrated steel plant built after the war in Brazil, and the gigantic fertilizer plant recently put into operation in India are examples of this new trend. A characteristic example in the U.S.A. was the creation of the great chemical industry when the country lost its source of chemicals in Germany after the outbreak of the first world war. The main difficulty was the lack of experienced chemical craftmen such as Germany had. The problem was solved, however, by the introduction of mechanization and automatization to a degree theretofore unknown. The same thing is now happening, and possibly will continue on a growing scale, in underdeveloped countries.

But automatization, while solving some problems, may create new and possibly more difficult ones. In the rising new countries economic efficiency may, at least temporarily, run far ahead of progress toward social maturity and stability. It remains to be seen whether these countries will find a driving force to help them develop the social, cultural and political advances necessary to help them cope with the new economic emancipation.

This article is one of a series of seven appearing in the same issue of *The Scientific American;* the other six deal with the technological aspect of automatization.

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